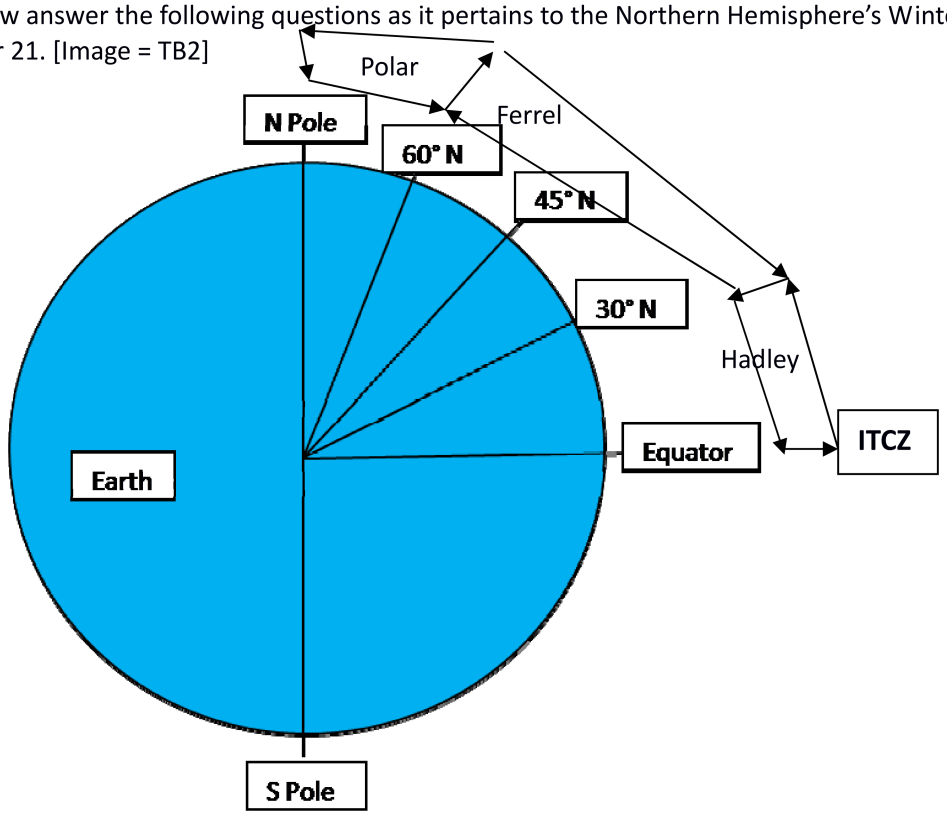
Causes of Earth's Weather:

For the image below answer the following questions as it pertains to the Northern Hemisphere's Winter Solstice, December 21. [Image = TB2]



21. How many hours of sunlight are there at the N Pole? (1 pt)
    0 Hours

22. How many hours of sunlight at S Pole? (1 pt)
    24 Hours

23. Approximately how many hours at the Equator? (1 pt)
    Approximately 12 Hours. The actual amount will be slightly less, as the sun is overhead at the Tropic of Cancer at this time.

24. In what direction is the Coriolis force acting (Right, Left, or None): (4 pts)
    a. N Pole. Right.
    b. 45° N. Right.
    c. Equator. None.
    d. S Pole. Left.

25. Imagine for a moment that there are no clouds anywhere on the Earth. Will the albedo be the greatest at the point marked N Pole, 45° N, Equator, or S Pole? (1 pt)

    S Pole.

26. Why did you choose the answer above? (2 pt) [TB3]

The North Pole has no sunlight, so there's nothing to reflect, and the South Pole is the only other location with a substantial ice sheet, which is very reflective.

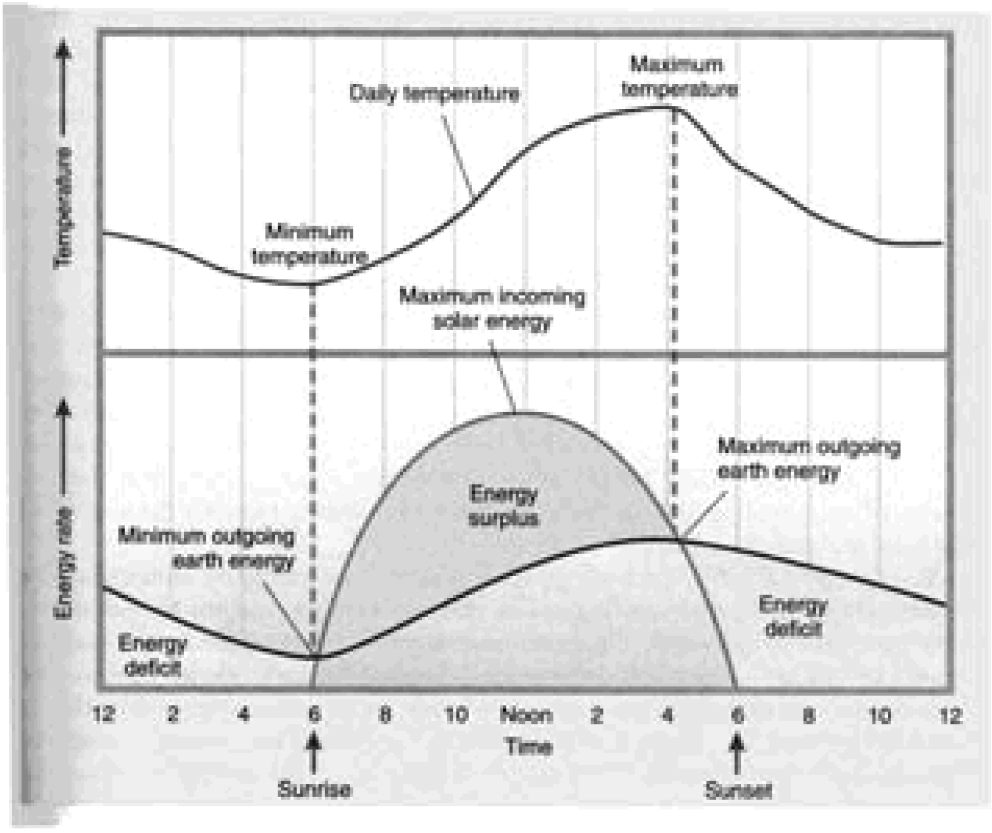
27. Draw on the image the Three-Cell Model (Polar Cell, Ferrel Cell, and Hadley Cell) for the Northern Hemisphere only. Note that each cell will include a surface wind, a wind aloft, and areas of rising or sinking air. (6 pts – 2 each for vertical/horizontal parts being correct)

28. Label the location of the intertropical convergence zone by writing ITCZ on the image. (1 pt)

29. At what location would you find a persistent subtropical high? (1 pt)

30 Degrees N Latitude

Understanding Heating:



Use the diagram above to answer the following questions:

30. At what time is the maximum temperature reached? (1 pt)
Approximately 4 PM

31. Which maximizes later in the day: incoming solar energy or outgoing earth energy? (1 pt)

    Outgoing earth earth energy _____

32. Why does the maximum temperature not occur at the same time as the time when maximum incoming solar radiation? (2 pts) [TB4]

    The temperature keeps warming up until the outgoing earth energy, which is dependent on temperature, is greater than the incoming solar energy. _____

Optical Phenomena

From the image above, answer the following questions:

33. What is the name of the feature shown in the image above? (1 pt)

A double rainbow

34. A rainbow is formed when sunlight undergoes what process? Circle the best answer. (1 pt)

(Refraction) Dispersion Reflection Mirage

35. The faint rainbow on the outside is somewhat rare. What must happen within the raindrops in order for this second rainbow to form? (2 pts) [TB5]

The refracted light must be reflected inside the drop a second time. The reflection causes you to see the rainbow, but the refraction actually scatters the light into its colors.

Humidity:

36. Relative Humidity is a good measure of the total amount of water vapor in the air. (1 pt)

True (False)

37. Relative Humidity can change only when the air's water vapor content changes. (1 pt)

True (False)

Circle the best answer:

38. If the amount of water vapor remains constant, then _____ the air raises the Relative Humidity and _____ the air lowers it. (1 pt)

a. Warming, cooling

b. Warming, warming

(c. Cooling, warming)

d. Cooling, cooling

Fog:

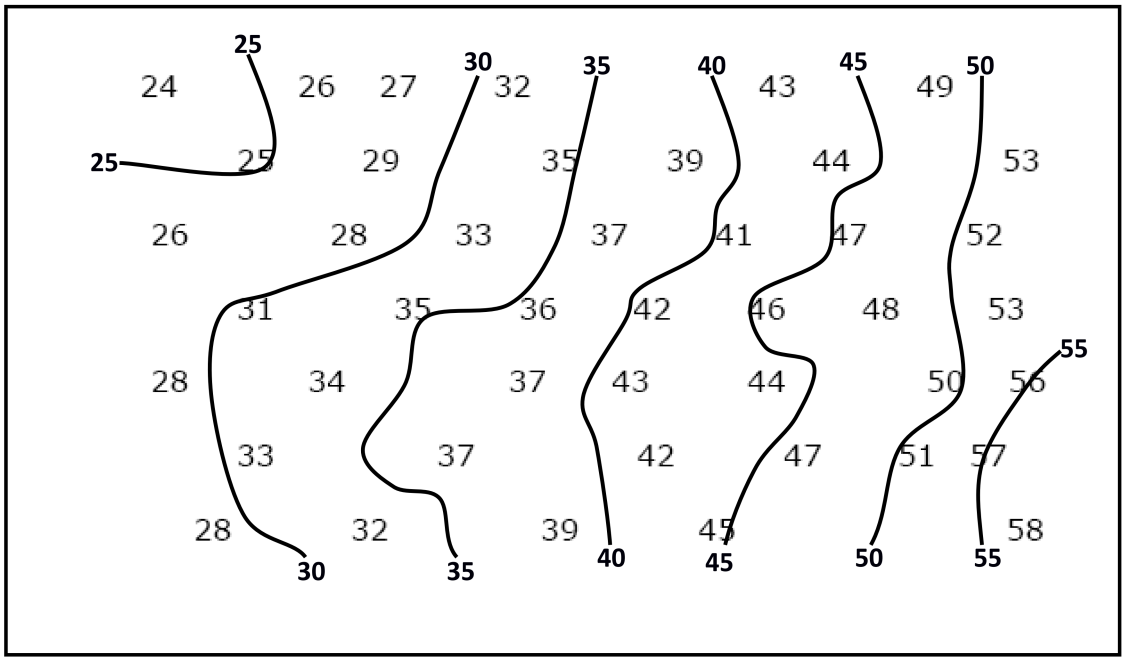
39. Match the type of fog on the left with the description on the right. (5 pts)

_a_ Radiation fog	a) It's a clear and calm night, and the temperature cools to near the dew point.
_c_ Upslope fog	b) Warm, moist air from the Pacific Ocean is carried by the westerly winds over the cold coastal waters of San Francisco and the air temperature is chilled from below.
_d_ Evaporation Fog	c) Moist air that flows up the Rockies Mountains.
_e_ Frontal Fog	d) The mixing of two unsaturated masses of air.
_b_ Advection Fog	e) Fog that is associated with warm air riding up and over a

mass of colder surface air.

Crazy about Contouring

Given the temperatures reported from various stations as plotted below (in degrees Fahrenheit):



40. Draw and label the isotherms (contour lines of equal temperature) every 5 degrees, starting at 25 degrees. (7 pts) [TB1]

Meteorologists analyze several different atmospheric variables to create their forecasts. One of these variables is atmospheric pressure.

41. What are lines of equal pressure called? (1 pt)

    isobars

42. When lines of equal pressure are closer together, wind speeds are faster. (1 pt)

    (True) False

43. List three ingredients needed for thunderstorm formation (3 pts)

    a. moisture

    b. heat or instability

    c. lift (will accept something that does this, like a front or dryline)

44. What additional ingredient is required for severe thunderstorms? (1 pt)

    Wind shear

National Science Olympiad 2010
Meteorology (Everyday Weather)

Event Booklet

Instructions:

Remember, you have **50 minutes**, so use your time wisely. If you don't know the answer to a question, you may wish to skip it and go on. An announcement will go out when 30 minutes, 15 minutes, and 5 minutes remain. If you finish early, you may wish to check over your answers.

Remember to include units in your answers!

You may use one 8.5 X 11" page of notes, front and back, as well as a calculator. If you have any questions, or are concerned about anything, please ask one of the event supervisors for help. Good luck and have fun!

Remember to write your names and school in the blanks below!

Write your names and school in the blanks below.

Name: _____

Name: _____

School Name: _____

School Number: _____

Identifying Energy Transfers

1. The following statements best describe convection, conduction, or radiation. Put an "A" in the blank next to the statement if you think it was convection, a "B" for conduction, or a "C" for radiation:

   _____ A metal bar glows a dull red after being heated.

   _____ Pepper flakes circulate around and around in a pot of heated water.

   _____ Smoke rises from a fireplace.

   _____ The end of a spoon gets too hot to touch as you stir a hot liquid.

   _____ The air touching the ground heats up during the day.

   _____ Photons are absorbed by the International Space Station, heating it.

Atmospheric Structure and Composition

Circle "True", if you think the statement below is true, and "False" if you think it is false.

2. The ozone layer is primarily found within the troposphere.

   True False

3. Approximately 80% of air in the atmosphere is found in the thermosphere.

   True False

4. The troposphere, stratosphere, and mesosphere are composed mainly of nitrogen and oxygen, but the thermosphere is composed mainly of hydrogen and helium.

   True False

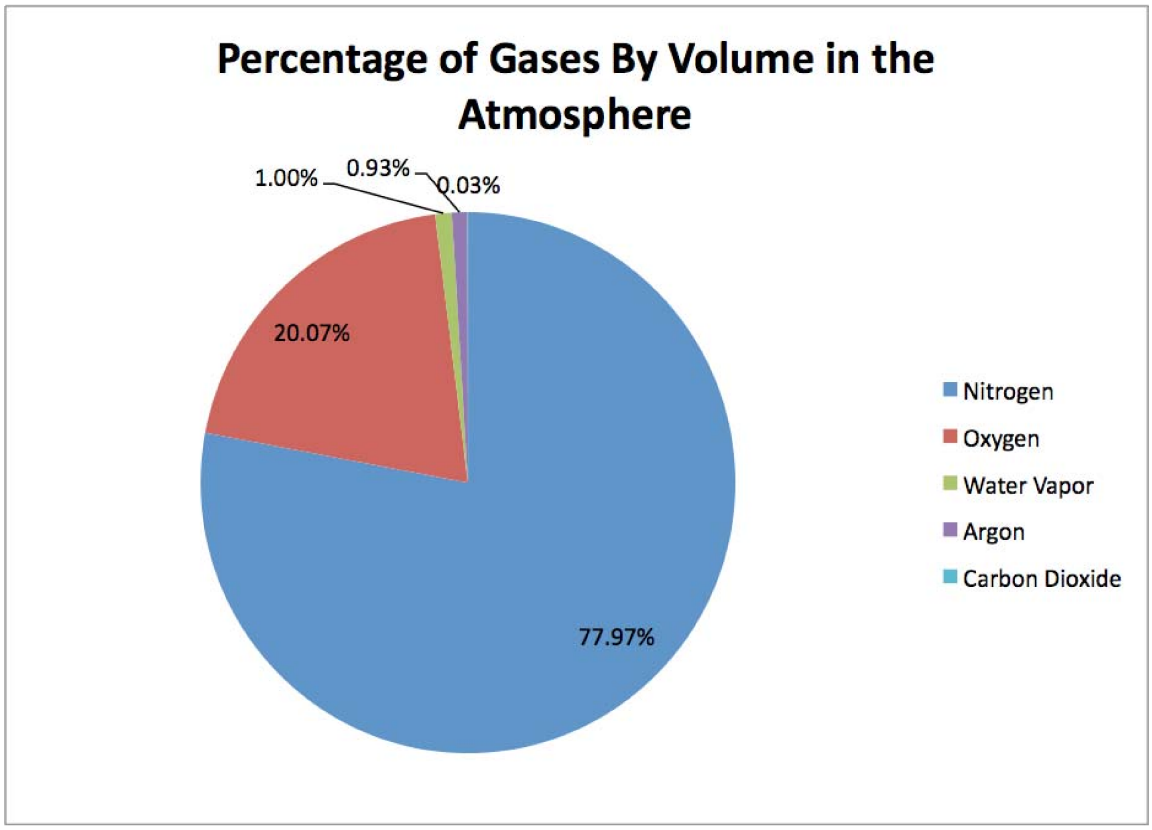
5. Pilots flying near lines of thunderstorms frequently have to fly into the mesosphere to get around them.

   True False

6. Noctilucent clouds form in the mesosphere.

   True False

The pie graph below shows the average composition of the Earth's atmosphere by volume. Use the graph to answer the following questions.



7. What percentage of the atmosphere is made up of Oxygen?

_____

8. Which is more common, Water Vapor or Argon?

_____

9. What percentage of the atmosphere is made up of Nitrogen?

_____

10. What percentage is NOT made up of Nitrogen or Oxygen?

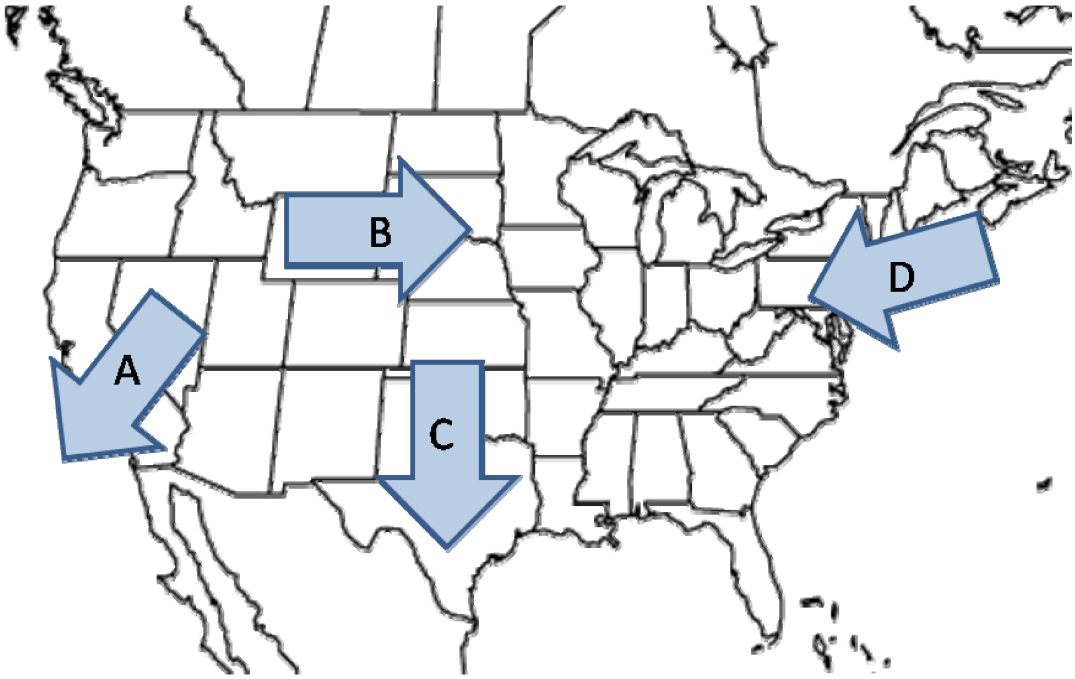
_____

Understanding Pressure

11. If normal atmospheric pressure is 14.7 pounds/sq in at the surface of the Earth, what is the force pushing down on a table measuring 50 inches wide by 200 inches long? Remember to show your work!

Regional Winds

12. Many winds have local or regional names. The map below shows four arrows representing the location and direction of a regional wind. Write the letter inside each arrow in the blank next to the name that describes that wind :



____ Chinook
____ Santa Ana

____ Blue Norther
____ Noreaster

13. Which of the winds above are typically warm winds and which are cold?

    Warm: _____

    Cold: _____

14. Which of the winds above are frequently accompanied by rain or snow?

    _____

    _____

    _____

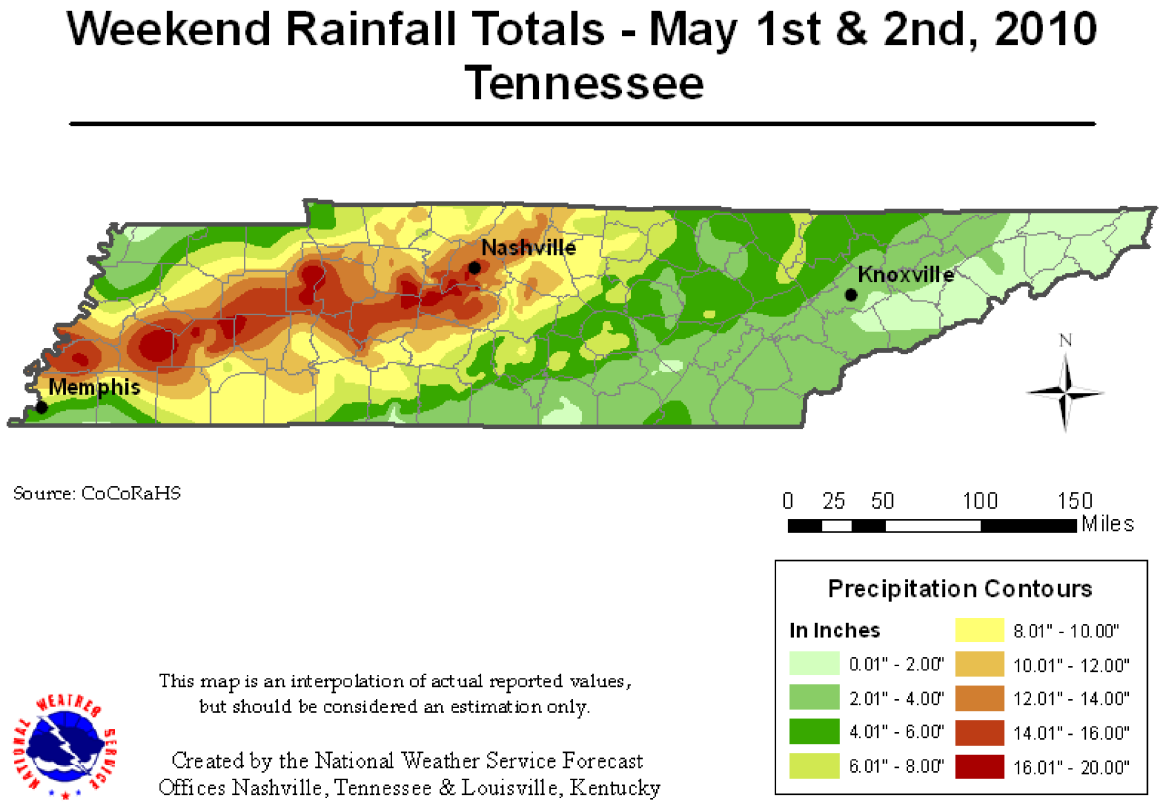
Fronts and Airmasses

15. Match the following frontal types on the left with the appropriate description on the right.

____ Warm Front	a. A boundary in which neither warm nor cools moves substantially.
____ Cold Front	b. A boundary that forms when a cold front overtakes a warm front.
____ Stationary Front	c. A boundary between an advancing warm airmass and a retreating cold one.
____ Occluded Front	d. A boundary in which cold or cool air forms a wedge, displacing warmer air.

Heavy Precipitation

Look at the following map of precipitation values and use it to answer the questions below.



16. Approximately how much rain fell at the following cities (use your best estimate)?

    Memphis: _____

    Nashville: _____

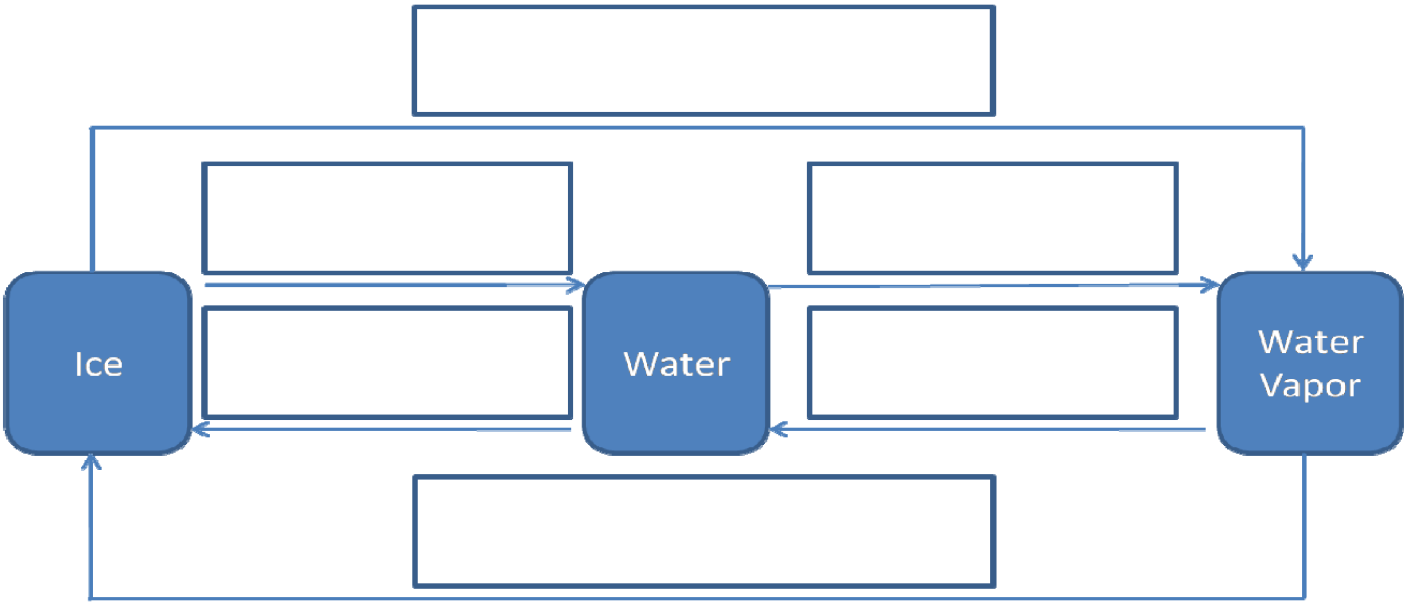
    Knoxville: _____

17. Would you be more likely to issue a flood warning for the Western Half OR the Eastern Half of Tennessee, based on the map?

    Western Half Eastern Half

States of Water

18. The following diagrams represent the ways in which water changes phase. Write the proper term from the list of words below in each blank.



Sublimation	Freezing	Evaporation
Deposition	Melting	Condensation

Radiation and Optics

Circle the bold word in each pair that makes the sentence true.

19. Red light has a **longer | shorter** wavelength than blue light, therefore it tends to refract **more | less** when moving from air to water.

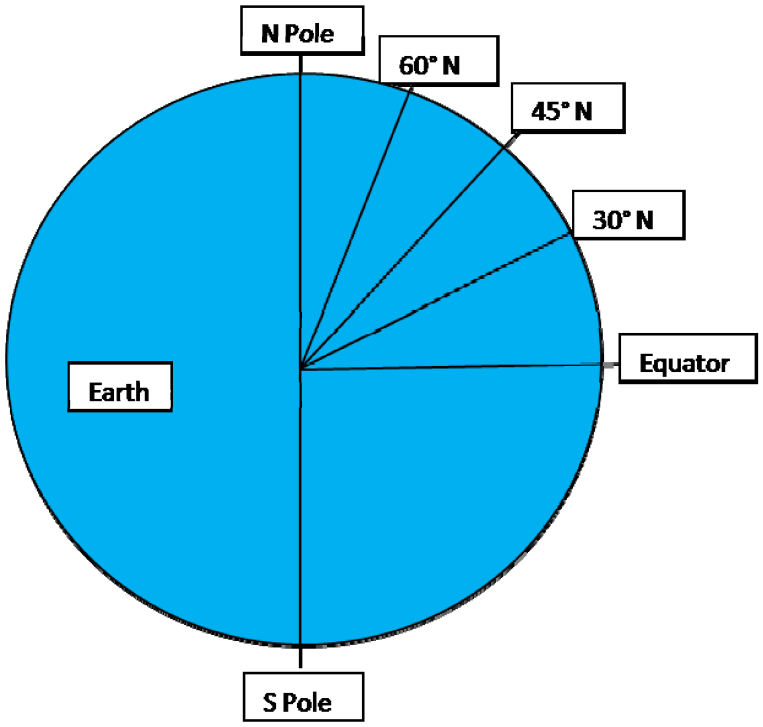
Radiation Budget:

20. It's an overcast day across the Midwest and only 20% of the available incoming solar radiation is able to reach the surface in Urbana, IL. If the amount of solar radiation that is absorbed by the atmosphere and clouds remains constant, then how much will be scattered and reflected by the Earth's surface, clouds, and atmosphere (in total)? Hint: disregard the infrared side of the solar energy budget for this question.

_____

Causes of Earth's Weather:

For the image below answer the following questions as it pertains to the Northern Hemisphere's Winter Solstice, December 21.



21. How many hours of sunlight are there at the N Pole? _____

22. How many hours of sunlight at S Pole? _____

23. Approximately how many hours at the Equator? _____

24. In what direction is the Coriolis force acting (Right, Left, or None) at the following locations:

    a. N Pole. _____

    b. 45° N. _____

    c. Equator. _____

    d. S Pole. _____

25. Imagine for a moment that there are no clouds anywhere on the Earth. Will the albedo be the greatest at the point marked N Pole, 45° N, Equator, or S Pole?

    _____

26. Why did you choose the answer above?

_____

_____

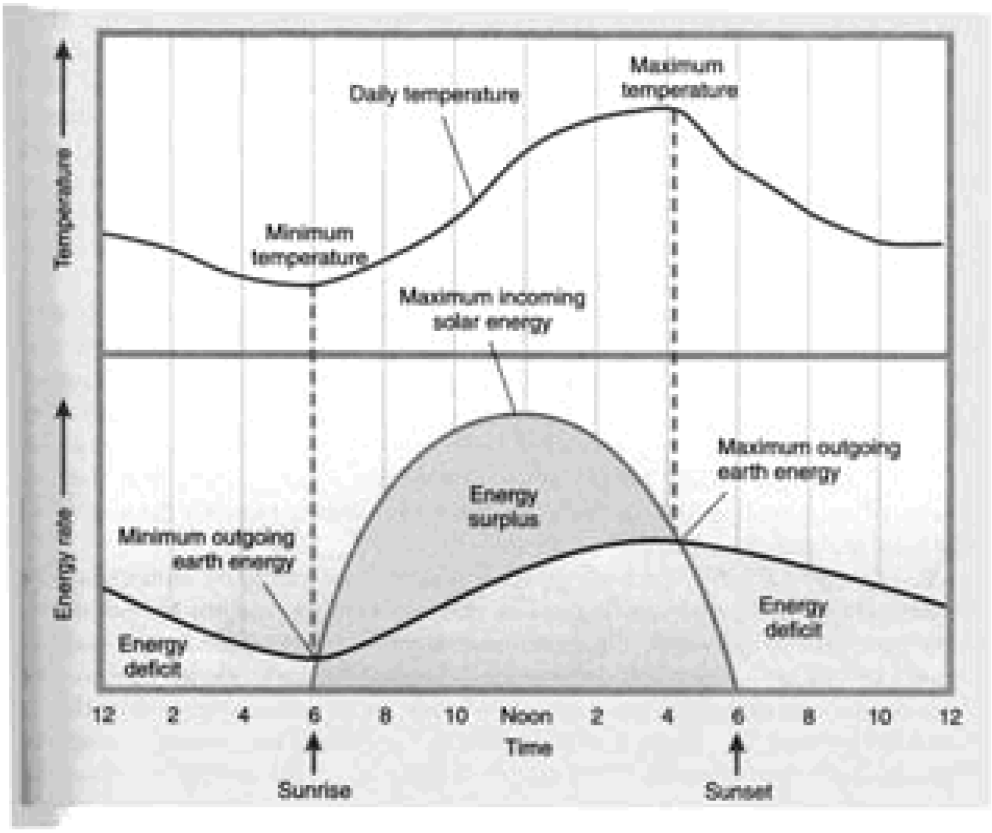
_____

27. Draw on the image the Three-Cell Model (Polar Cell, Ferrel Cell, and Hadley Cell) for the Northern Hemisphere only. Note that each cell will include a surface wind, a wind aloft, and areas of rising or sinking air.

28. Label the location of the intertropical convergence zone by writing ITCZ on the image.

29. At what location would you find a persistent subtropical high? _____

Understanding Heating:



Use the diagram above to answer the following questions:

30. At what time is the maximum temperature reached? _____

31. Which maximizes later in the day: incoming solar energy or outgoing earth energy?

_____

32. Why does the maximum temperature not occur at the same time as the time when maximum incoming solar radiation?

_____

_____

Optical Phenomena

From the image above, answer the following questions:

33. What is the name of the feature shown in the image above?

_____

34. A rainbow is formed when sunlight undergoes what process? Circle the best answer.

Refraction Dispersion Reflection Mirage

35. The faint rainbow on the outside is somewhat rare. What must happen within the raindrops in order for this second rainbow to form?

_____

_____

Humidity:

36. Relative Humidity is a good measure of the total amount of water vapor in the air.

True False

37. Relative Humidity can change only when the air's water vapor content changes.

True False

Circle the best answer:

38. If the amount of water vapor remains constant, then _____ the air raises the Relative Humidity and _____ the air lowers it.

    a. Warming, cooling

    b. Warming, warming

    c. Cooling, warming

    d. Cooling, cooling

Fog:

39. Match the type of fog on the left with the description on the right.

___ Radiation fog	a) It's a clear and calm night, and the temperature cools to near the dew point.
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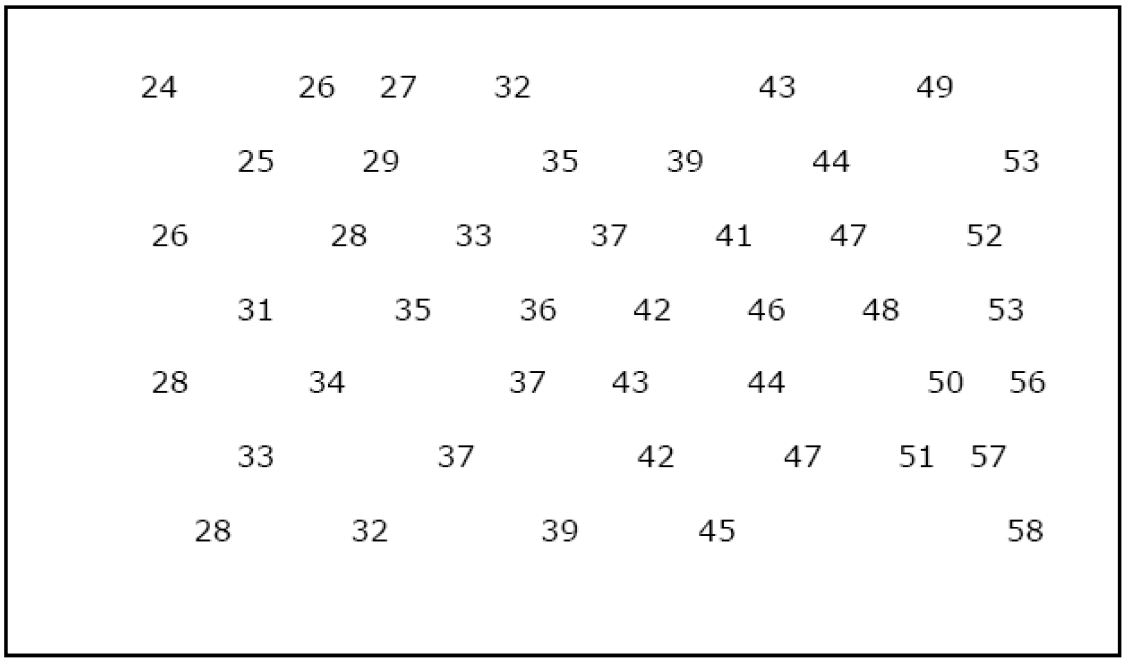
Crazy about Contouring

Given the temperatures reported from various stations as plotted below (in degrees Fahrenheit):



40. Draw and label the isotherms (contour lines of equal temperature) every 5 degrees, starting at 25 degrees.

Meteorologists analyze several different atmospheric variables to create their forecasts. One of these variables is atmospheric pressure.

41. What are lines of equal pressure called?

    _____

42. When lines of equal pressure are closer together, wind speeds are faster.

    True False

43. List three ingredients needed for thunderstorm formation

    a. _____

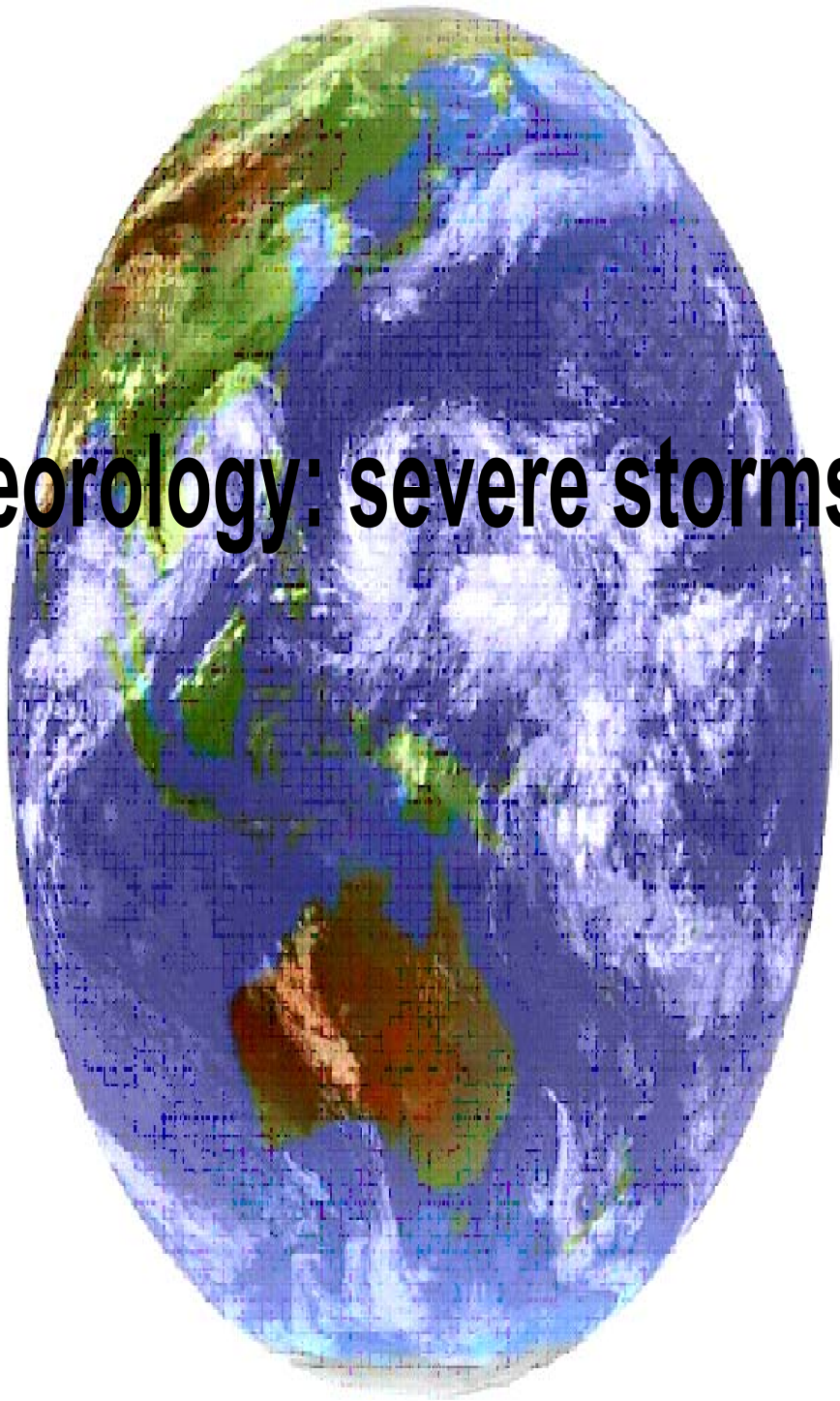
    b. _____

    c. _____

44. What additional ingredient is required for severe thunderstorms?

    _____

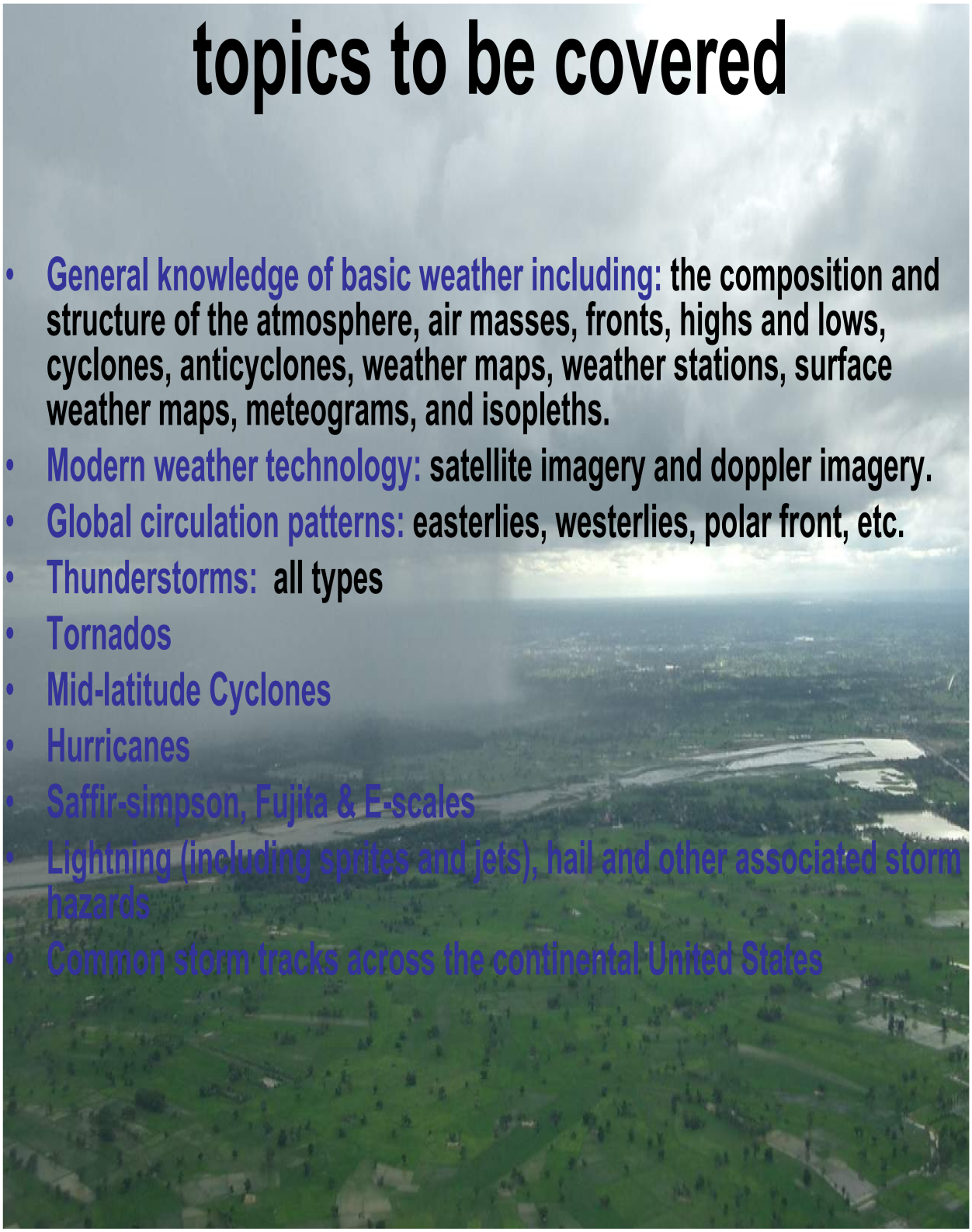
Meteorology: severe storms



Meteorology: Severe Storms

- **Severe Weather:** is the second topic in the B-Division Science Olympiad Meteorology Event.
- **Topics:** rotate annually so a middle school participant may receive a comprehensive course of instruction in meteorology during the three-year cycle.
- **Sequence:**
  1. Everyday Weather (2010)
  2. Severe Storms (2008)
  3. Climate (2009)

topics to be covered



- General knowledge of basic weather including: the composition and structure of the atmosphere, air masses, fronts, highs and lows, cyclones, anticyclones, weather maps, weather stations, surface weather maps, meteograms, and isopleths.
- Modern weather technology: satellite imagery and doppler imagery.
- Global circulation patterns: easterlies, westerlies, polar front, etc.
- Thunderstorms: all types
- Tornados
- Mid-latitude Cyclones
- Hurricanes
- Saffir-simpson, Fujita & E-scales
- Lightning (including sprites and jets), hail and other associated storm hazards
- Common storm tracks across the continental United States

General knowledge – composition and structure of the atmosphere

- **ITS COMPOSITION**
- **There are permanent gasses (nitrogen and oxygen)**
- **There are variable gasses (carbon dioxide, methane, water vapor, ozone, particulates**
- **The composition of the atmosphere has not been constant but has changed through time.**
- **We used to be the stuff of stars (helium and hydrogen) but outgassing, comets, UV radiation and photosynthesis have changed us.**

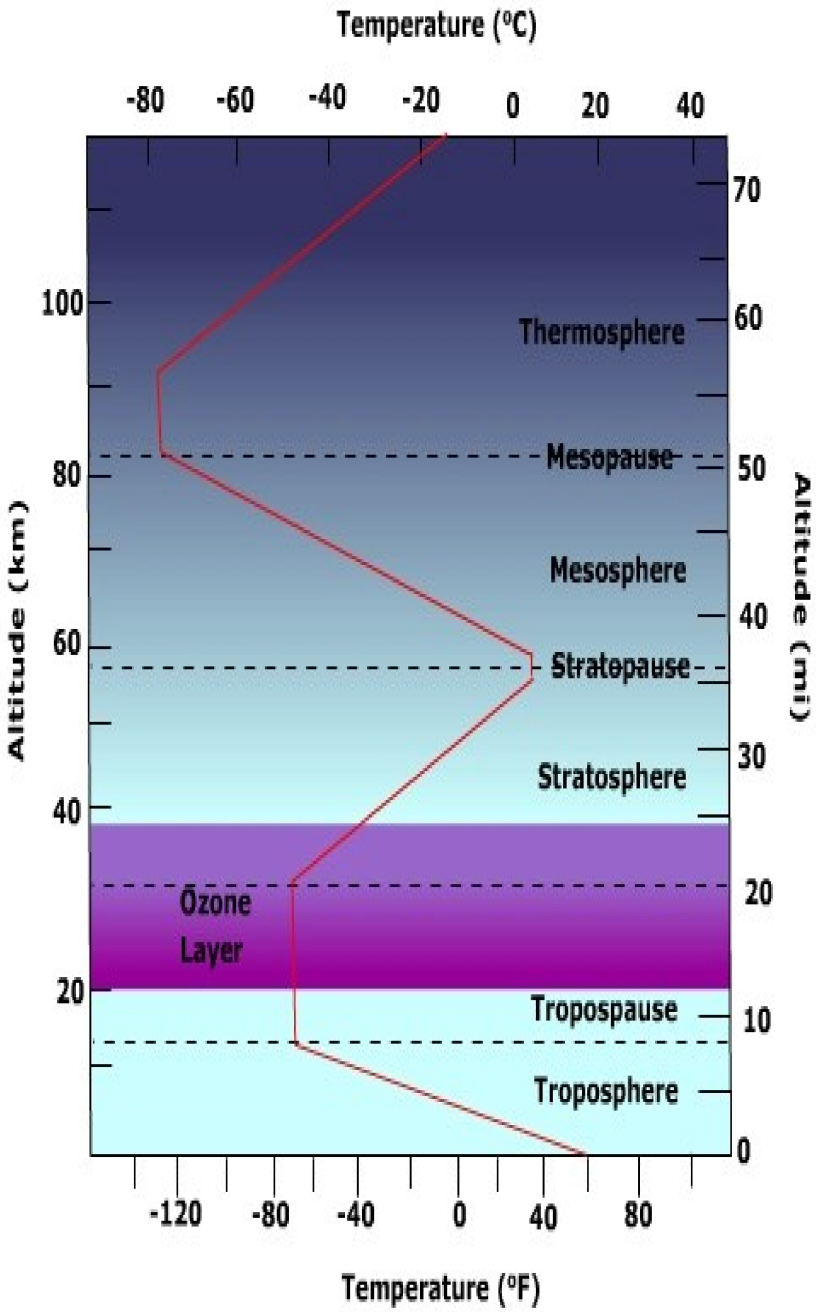
Constant components *(proportions remain the same over time and location)*	
Nitrogen (N_2)	78.08%
Oxygen (O_2)	20.95%
Argon (Ar)	0.93%
Neon, Helium, Krypton	0.0001%

Variable components *(amounts vary over time and location)*	
Carbon dioxide (CO_2)	0.0003%
Water vapor (H_2O)	0-4%
Methane (CH_4)	*trace*
Sulfur dioxide (SO_2)	*trace*
Ozone (O_3)	*trace*
Nitrogen oxides (NO, NO_2)	*trace*

- http://www.uwsp.edu/gEo/faculty/ritter/geog101/textbook/atmosphere/atmospheric_structure.html
- http://www.physicalgeography.net/fundamentals/7a.html
- http://www.visionlearning.com/library/module_viewer.php?mid=107&l=&c3=
- http://www.globalchange.umich.edu/globalchange1/current/lectures/samson/evolution_atm/index.html#evolution

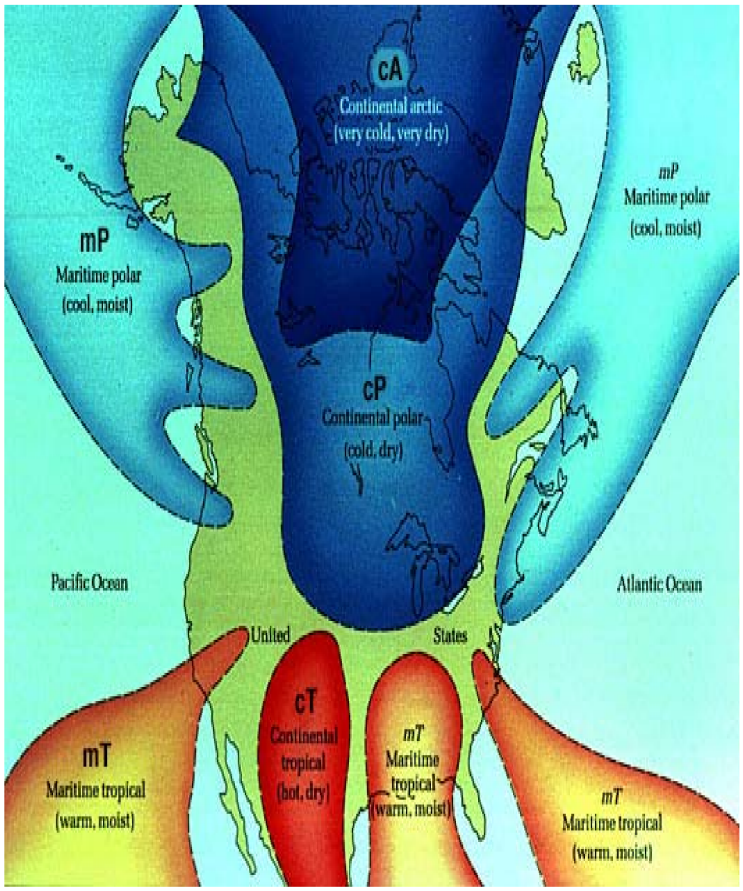
General knowledge – composition and structure of the atmosphere

- IT'S STRUCTURE
- Layers are defined by temperature, altitude, and unique characteristics
- There are layers where temperature rises with altitude or falls with altitude (our natural instinct).
- Between these layers there are pauses where temperature is constant with altitude change.
- Each layer has unique characteristics like 90% of the ozone is in the stratosphere and gasses stratify by molecular weight in the thermosphere
- Thickness of these layers varies with latitude.



- http://www.uwsp.edu/gEo/faculty/ritter/geog101/tephere/atmospheric_structure.html
- http://www.albany.edu/faculty/rgk/atm101/structur.htm

General knowledge – air masses



- Air masses tend to be homogeneous in nature. The two critical properties of any air mass are:
  - 1. Temperature
  - 2. Moisture
- The point of origin of an air mass will determine temperature and moisture content. Combined these properties produce the weather we experience daily.

- http://www.ecn.ac.uk/Education/air_masses.htm
- http://okfirst.ocs.ou.edu/train/meteorology/AirMasses.html

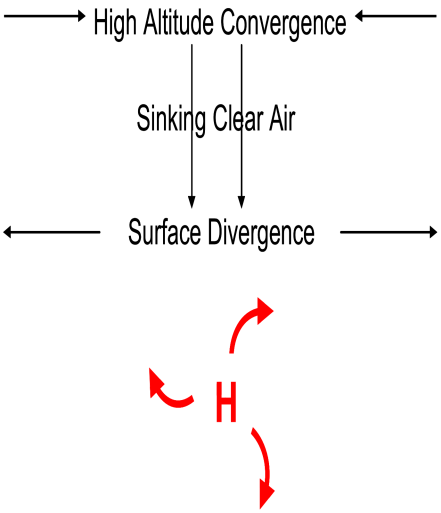
General knowledge – air masses

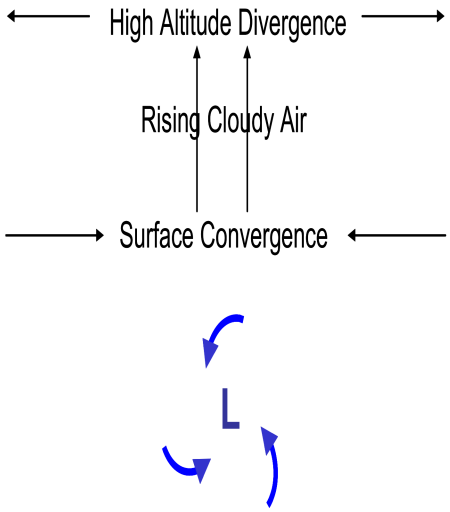
- An air mass is a huge volume of air that covers hundreds of thousands of square kilometers that is relatively uniform horizontally and vertically in both temperature and humidity
- The characteristics of an air mass are determined by the surface over which they form so they are either continental or maritime indicated with a lower case m or c
- Then they are classed as Arctic, Polar, Tropical or Equitorial (A, P, T, or E)
- And finally they have a lower case k or w at the end to indicate whether they are warmer or colder than the land over which they are moving.
- Note that arctic and polar are difficult to distinguish as are tropical and equatorial.
- Air masses are driven by the prevailing winds. Hot air originates near the equator and cold near the poles and the middle latitudes where we live is the mixing zone and we have spectacular weather as warm and cold air masses work their way across us.

General knowledge highs, lows, and fronts

- High pressure system is an anticyclone
- Highs generally have good weather and when seen from above surface winds surrounding a high blow in a clockwise direction and outward from the high
- Lows and highs track with the prevailing winds from west to east across the US

- Low pressure system is a cyclone
- Lows tend to have cloudy bad weather and when seen from above surface winds surrounding a low blow in a counter clockwise direction and inward to the low.
- Lows and highs track with the prevailing winds from west to east across the US



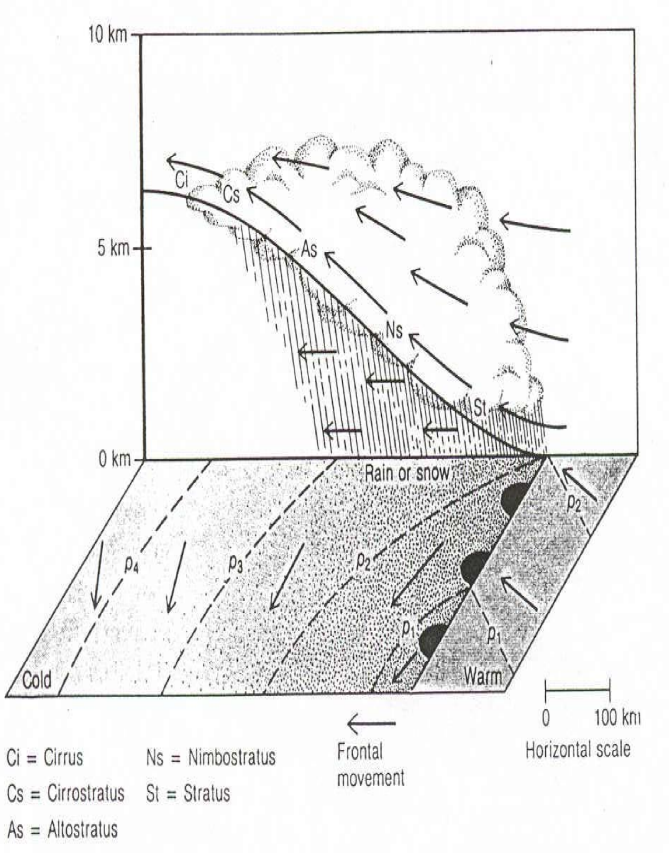


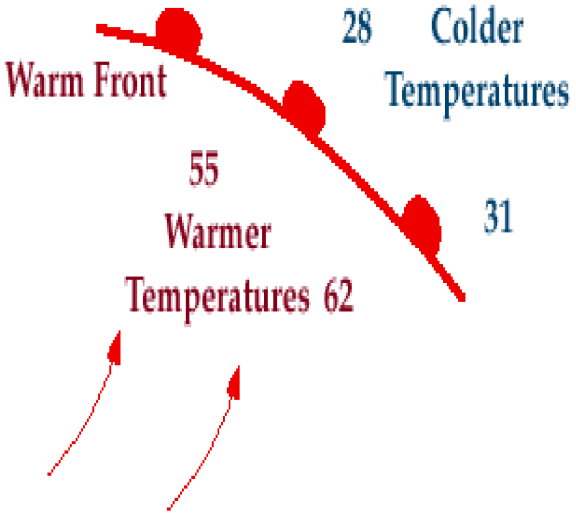
General knowledge highs, lows, and fronts

- As air masses collide carrying their characteristic temperature and moisture they create fronts: warm, cold, stationary and occluded.
- Each type of front has unique vertical characteristics with characteristic weather patterns.

General knowledge - warm fronts

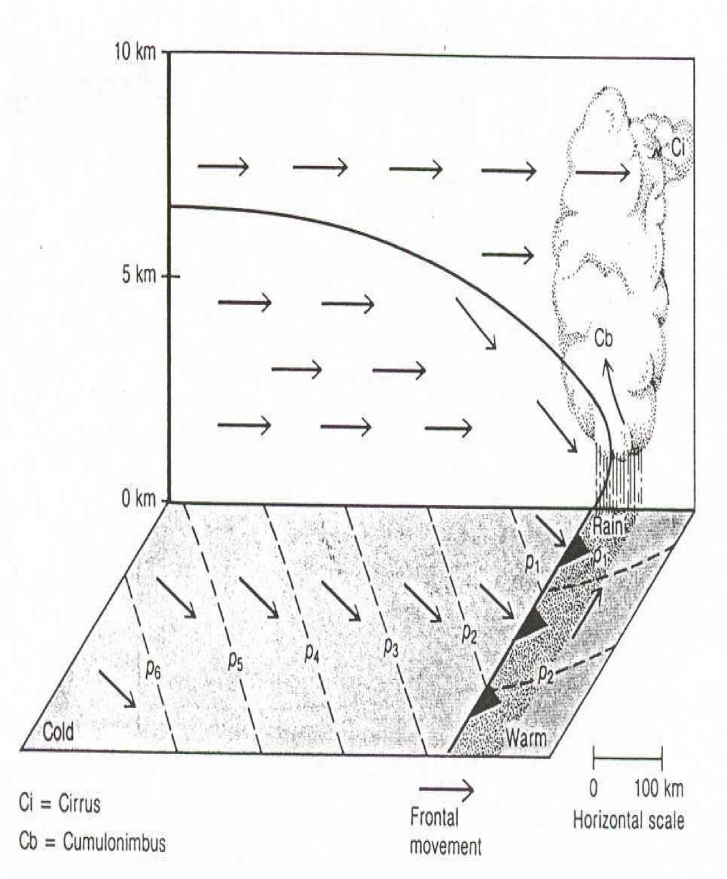
- Warm fronts tend to move slowly
- They carry broad bands of clouds that begin high and drop lower with time.
- They tend to be associated with light and prolonged rains and warming temperatures
- A warm front is defined as the transition zone where a warm air mass is replacing a cold air mass. Warm fronts generally move from southwest to northeast and the air behind a warm front is warmer and more moist than the air ahead of it. When a warm front passes through, the air becomes noticeably warmer and more humid than it was before.
- Symbolically, a warm front is represented by a solid line with semicircles pointing towards the colder air and in the direction of movement.

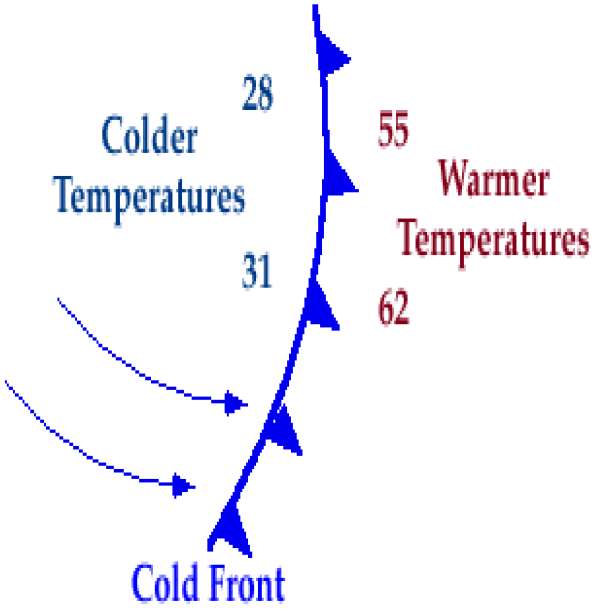




General knowledge - cold fronts

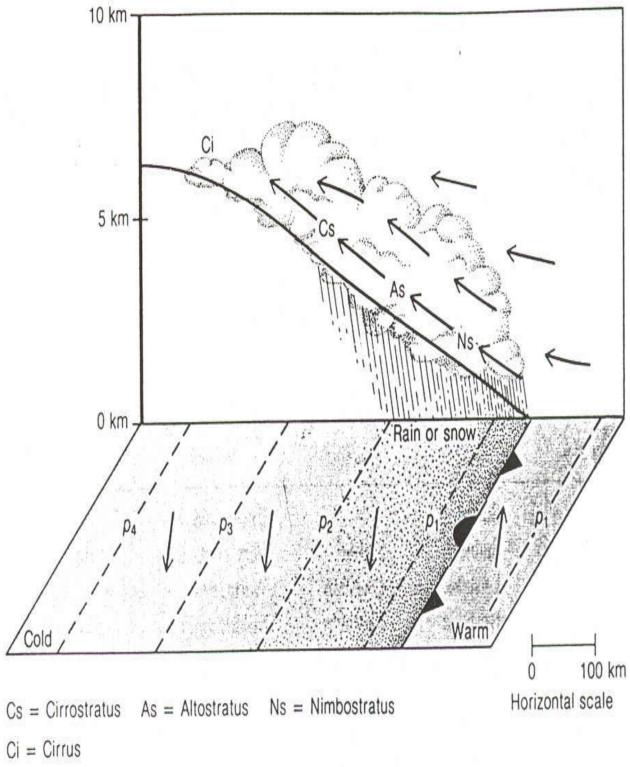
- A cold front is defined as the transition zone where a cold air mass is replacing a warmer air mass. Cold fronts generally move from northwest to southeast. The air behind a cold front is noticeably colder and drier than the air ahead of it. When a cold front passes through, temperatures can drop more than 15 degrees within the first hour.
- Cold fronts tend to be associated with vertical clouds and rains of short duration but often with intensity.
- There is typically a noticeable temperature change from one side of a cold front to the other. In the map of surface temperatures right, the station east of the front reported a temperature of 55 degrees Fahrenheit while a short distance behind the front, the temperature decreased to 38 degrees. An abrupt temperature change over a short distance is a good indicator that a front is located somewhere in between.
- Symbolically, a cold front is represented by a solid line with triangles along the front pointing towards the warmer air and in the direction of movement. On colored weather maps, a cold front is drawn with a solid blue line.

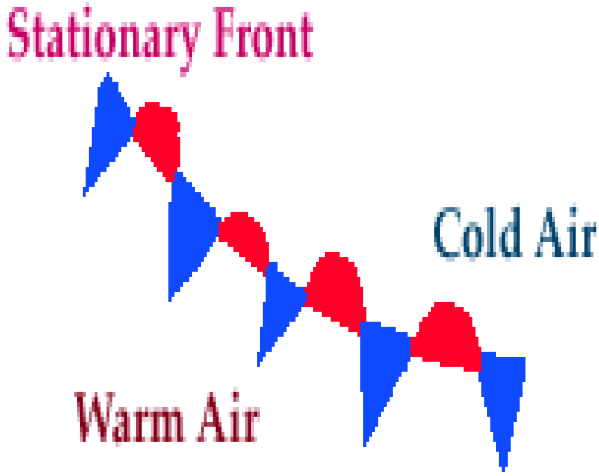




General knowledge - Stationary fronts

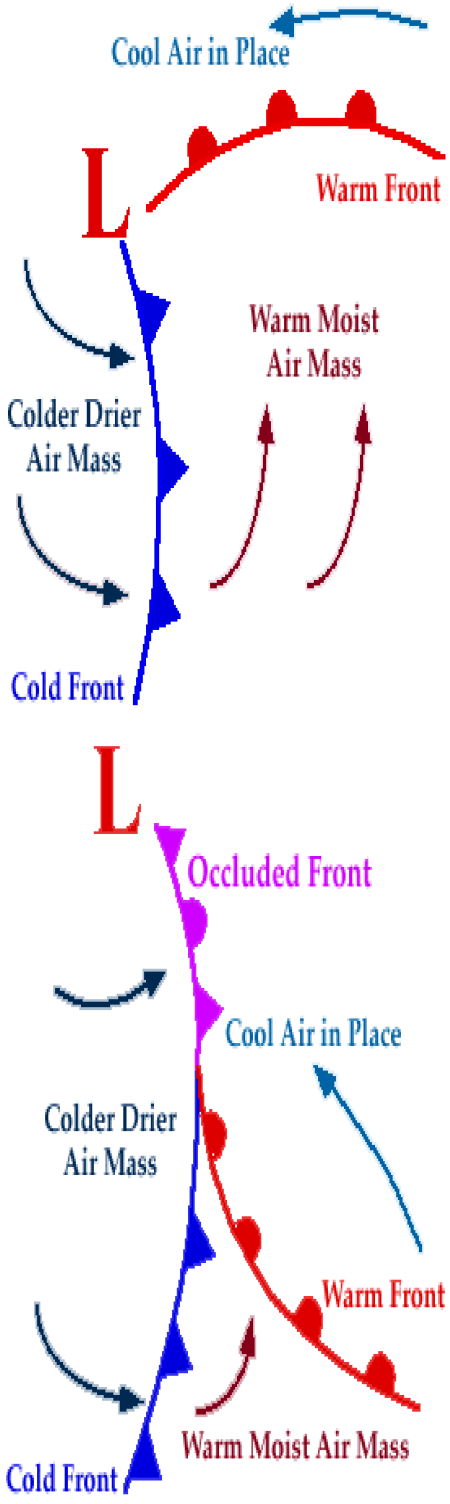
- When a warm or cold front stops moving, it becomes a stationary front. Once this boundary resumes its forward motion, it once again becomes a warm front or cold front. A stationary front is represented by alternating blue and red lines with blue triangles pointing towards the warmer air and red semicircles pointing towards the colder air.
- A noticeable temperature change and/or shift in wind direction is commonly observed when crossing from one side of a stationary front to the other.





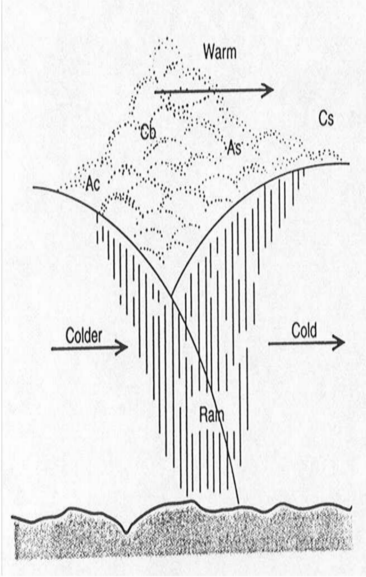
General Knowledge - Occluded fronts

- A developing cyclone typically has a preceding warm front (the leading edge of a warm moist air mass) and a faster moving cold front (the leading edge of a colder drier air mass wrapping around the storm). North of the warm front is a mass of cooler air that was in place before the storm even entered the region.
- As the storm intensifies, the cold front rotates around the storm and catches the warm front. This forms an occluded front, which is the boundary that separates the new cold air mass (to the west) from the older cool air mass already in place north of the warm front.
- Symbolically, an occluded front is represented by a solid line with alternating triangles and circles pointing the direction the front is moving. On colored weather maps, an occluded front is drawn with a solid purple line.
- Changes in temperature, dew point temperature, and wind direction can occur with the passage of an occluded front.
- A noticeable wind shift also occurred across the occluded front. East of the front, winds were reported from the east-southeast while behind the front, winds were from the west-southwest.

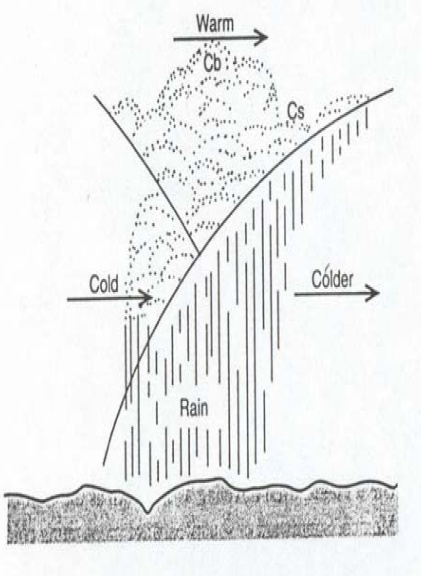


General knowledge - Warm or cold occluded fronts

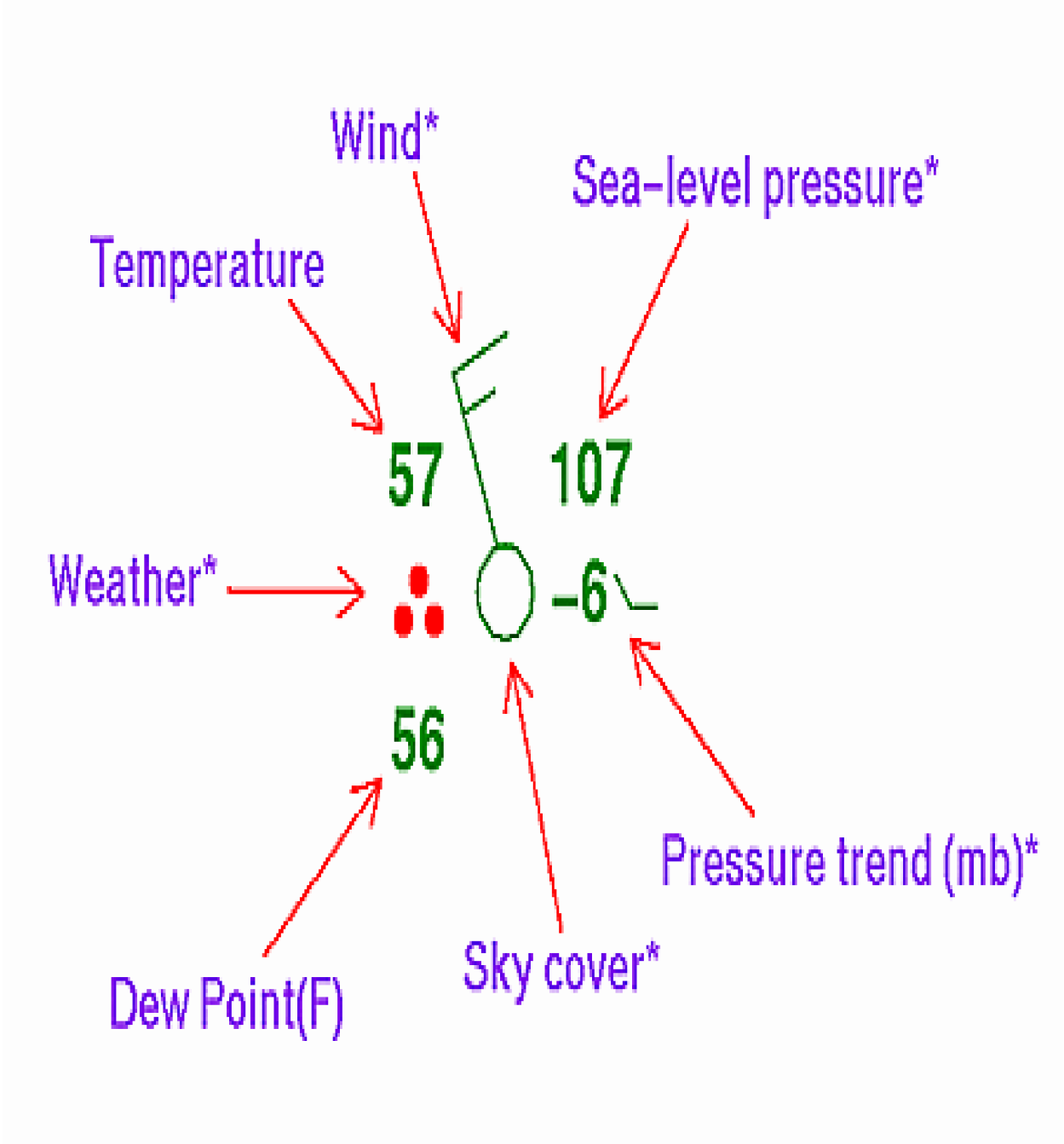
- Cold occlusion
- A colder air mass advances on a cold air mass and occludes warmer air.



- Warm occlusion
- A warmer air mass advances on a cold air mass and occludes warmer air.

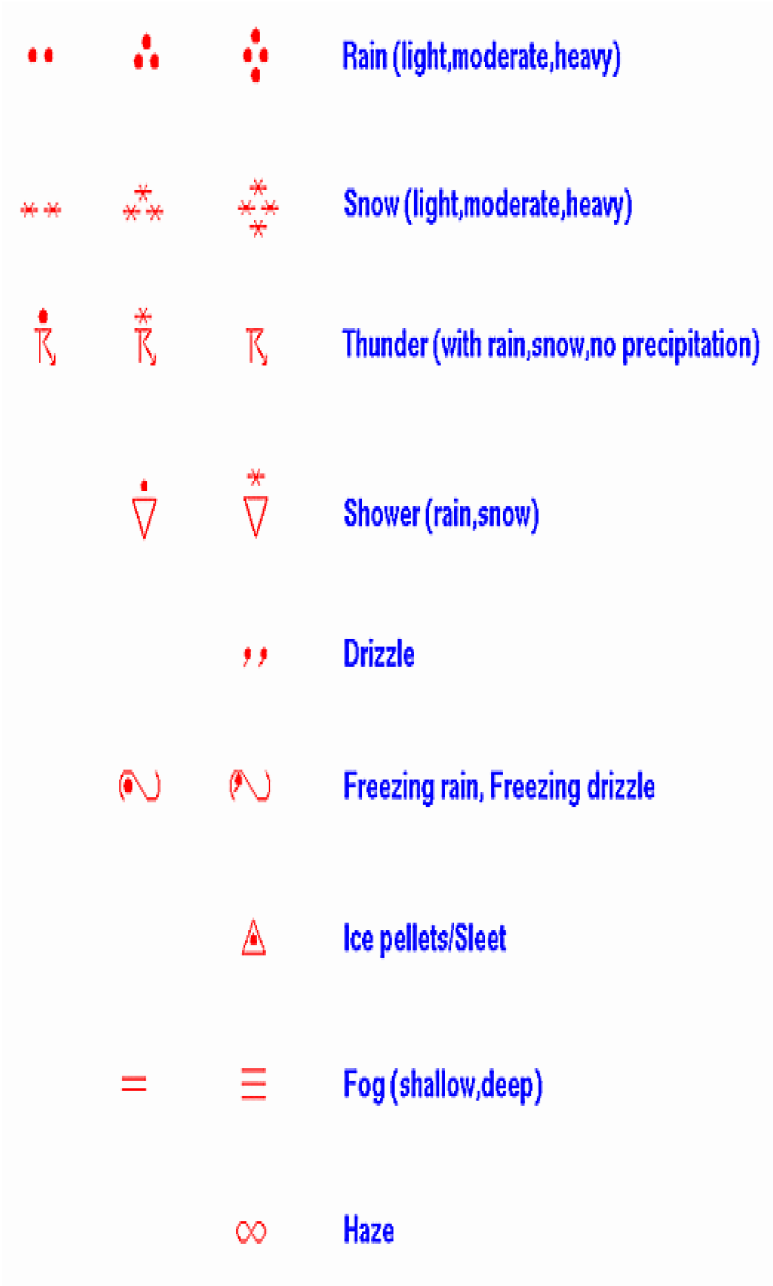


General knowledge - Surface weather stations



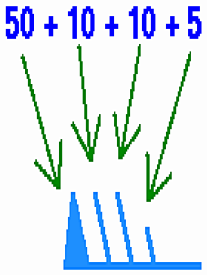
surface weather stations: current conditions

- A weather symbol is plotted if at the time of observation, there is either precipitation occurring or a condition causing reduced visibility.
  Below is a list of the most common weather symbols:



surface weather stations: wind speed and direction

- Wind is plotted in increments of 5 knots (kts), with the outer end of the symbol pointing toward the direction from which the wind is blowing.
- The wind speed is determined by adding up the total of flags, lines, and half-lines, each of which have the following individual values: flag: 50 kts, Line: 10 kts, Half-Line: 5 kts.
- Wind is always reported as the direction from which it is coming.
- If there is only a circle depicted over the station with no wind symbol present, the wind is calm. Below are some sample wind symbols:



Wind blowing from the west at 75 knots

Wind blowing from the northeast at 25 knots

Wind blowing from the south at 5 knots

Calm winds

surface weather stations: pressure and trend

- PRESSURE

Sea-level pressure is plotted in tenths of millibars (mb), with the leading 10 or 9 omitted. For reference, 1013 mb is equivalent to 29.92 inches of mercury. Below are some sample conversions between plotted and complete sea-level pressure values. If the surface weather station number is <500 place a leading 10 if it is >500 place a leading 9; then divide by 10:

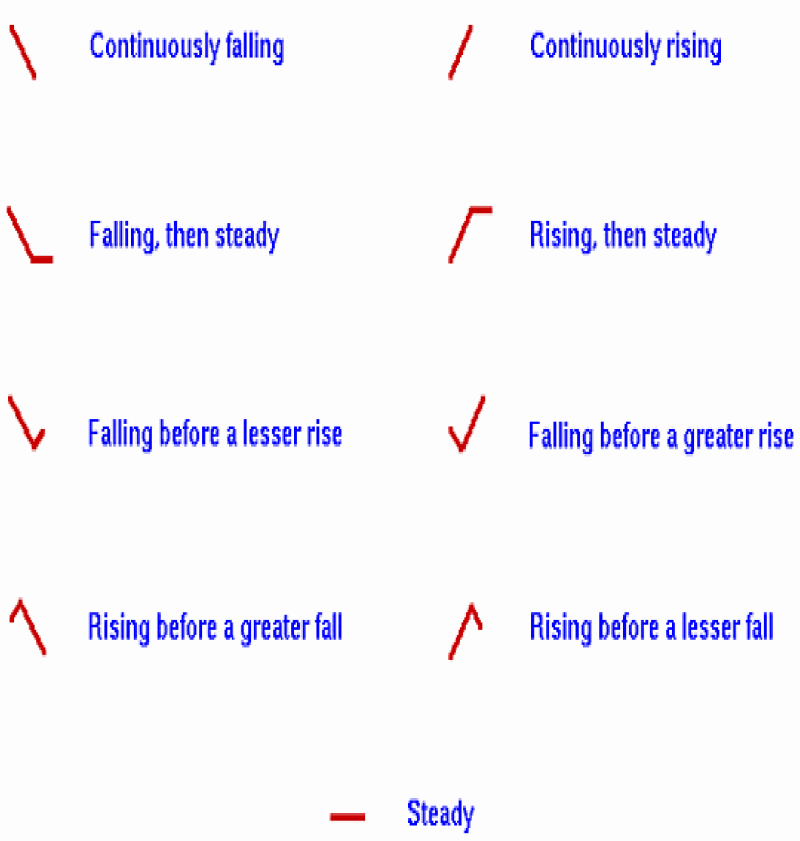
410: 1041.0 mb
103: 1010.3 mb
987: 998.7 mb
872: 987.2 mb

http://www.csgnetwork.com/meteorologyconvtbl.html

- http://ww2010.atmos.uiuc.edu/(Gh)/guides/maps/sfcobs/home.rxml

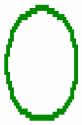
- PRESSURE TREND

The pressure trend has two components, a number and symbol, to indicate how the sea-level pressure has changed during the past three hours. The number provides the 3-hour change in tenths of millibars, while the symbol provides a graphic illustration of how this change occurred. Below are the meanings of the pressure trend symbols:



surface weather stations: sky cover

- The amount that the circle at the center of the station plot is filled in reflects the approximate amount that the sky is covered with clouds. To the right are the common cloud cover depictions



Clear

Scattered clouds
(approximately 25% cloud cover)

Partly cloudy
(approximately 50% cloud cover)

Mostly cloudy
(approximately 75% cloud cover)

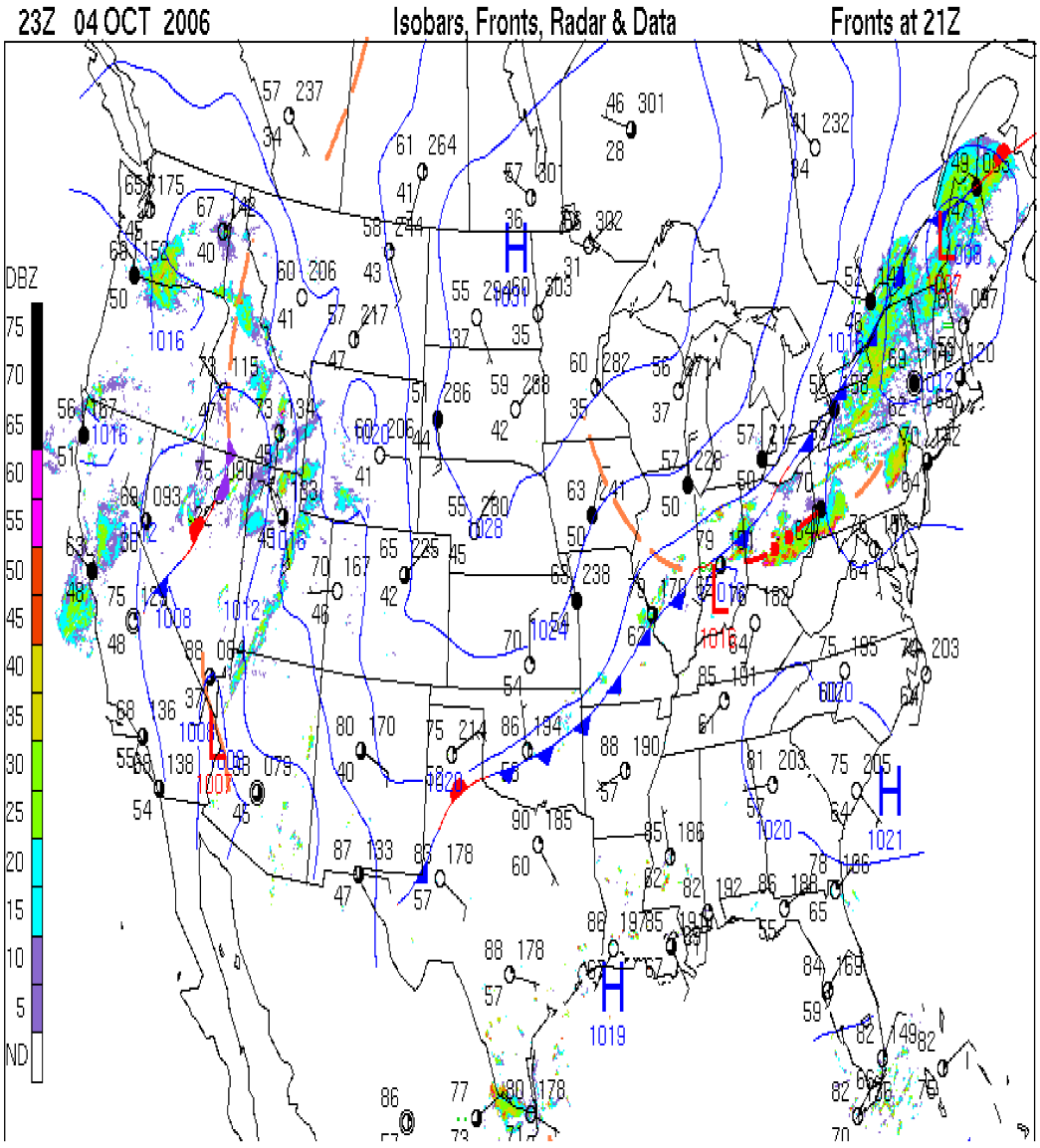
Overcast

Sky Obscured

Sky Cover Missing

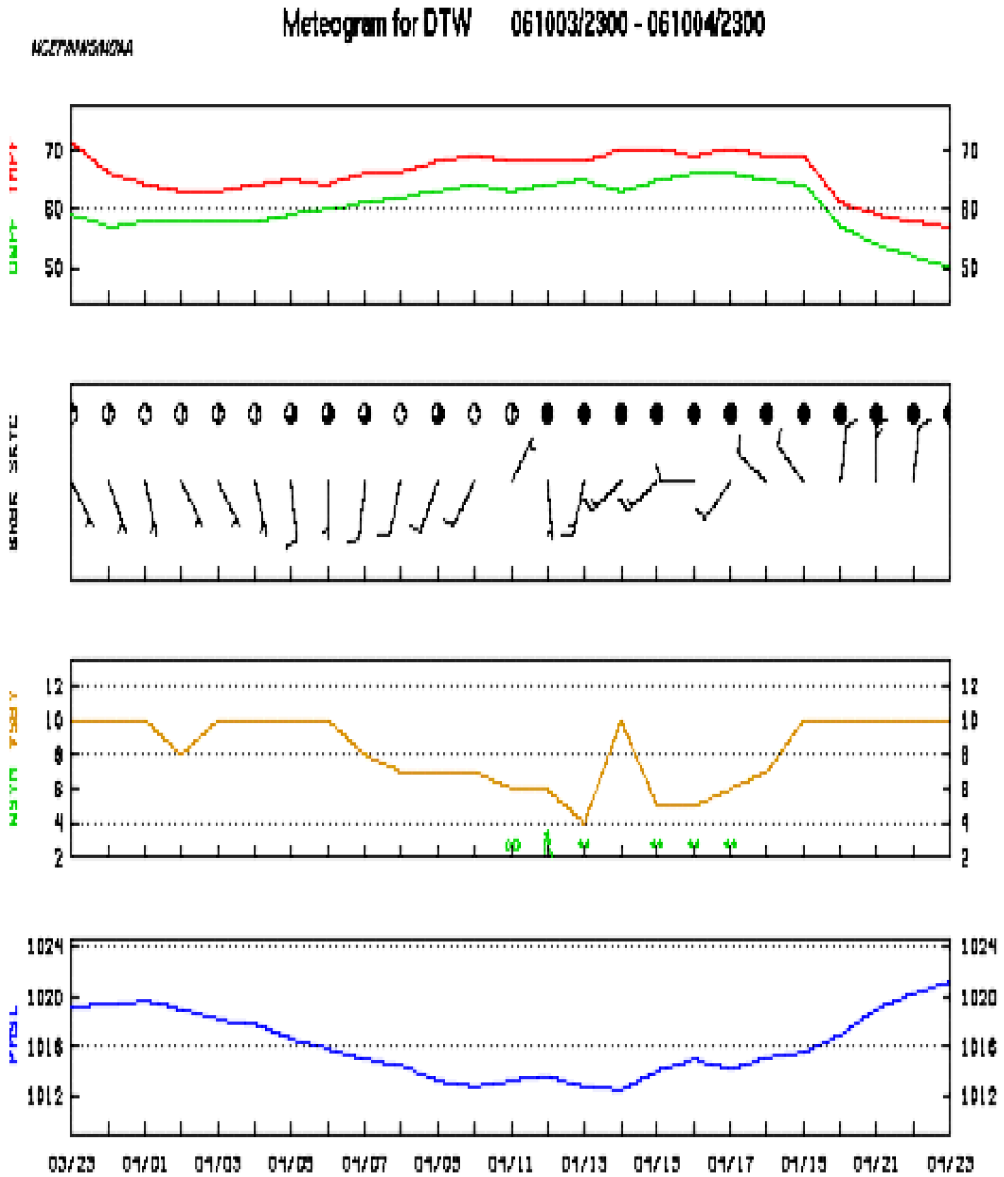
General knowledge - weather maps radar, fronts, isopleths and data

- There is a tremendous amount of information on maps like these and they make excellent material for test questions. For instance, what type of front is about to enter the state of Arkansas? What is the current wind direction and speed for the surface weather station in central New Mexico? Students need to know their state maps!



General knowledge - meteograms

- Meteograms give vast amounts of information about a given areas weather over a 24 hour period. Great thinking questions can be drawn from this material

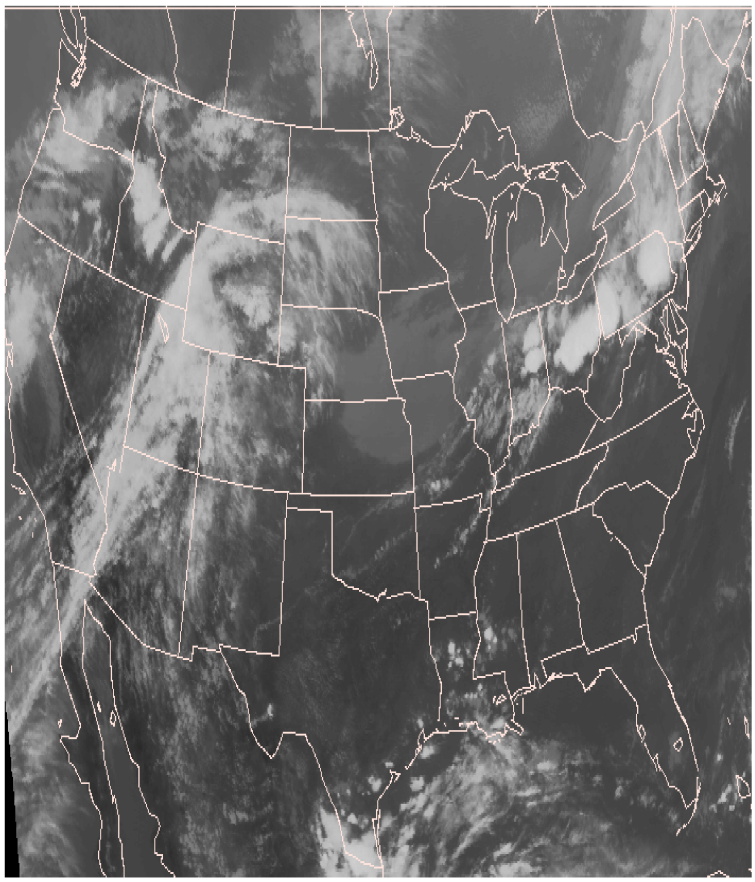


modern weather technology
satellites and radar imagery

- With the advent of satellites and radar vast amounts of weather data may be observed . . . It is learning what it all means and what it can do for us that is important.
- Lets look at some of the types of data collected by these satellites.
- These types of images are great ways to view severe storms

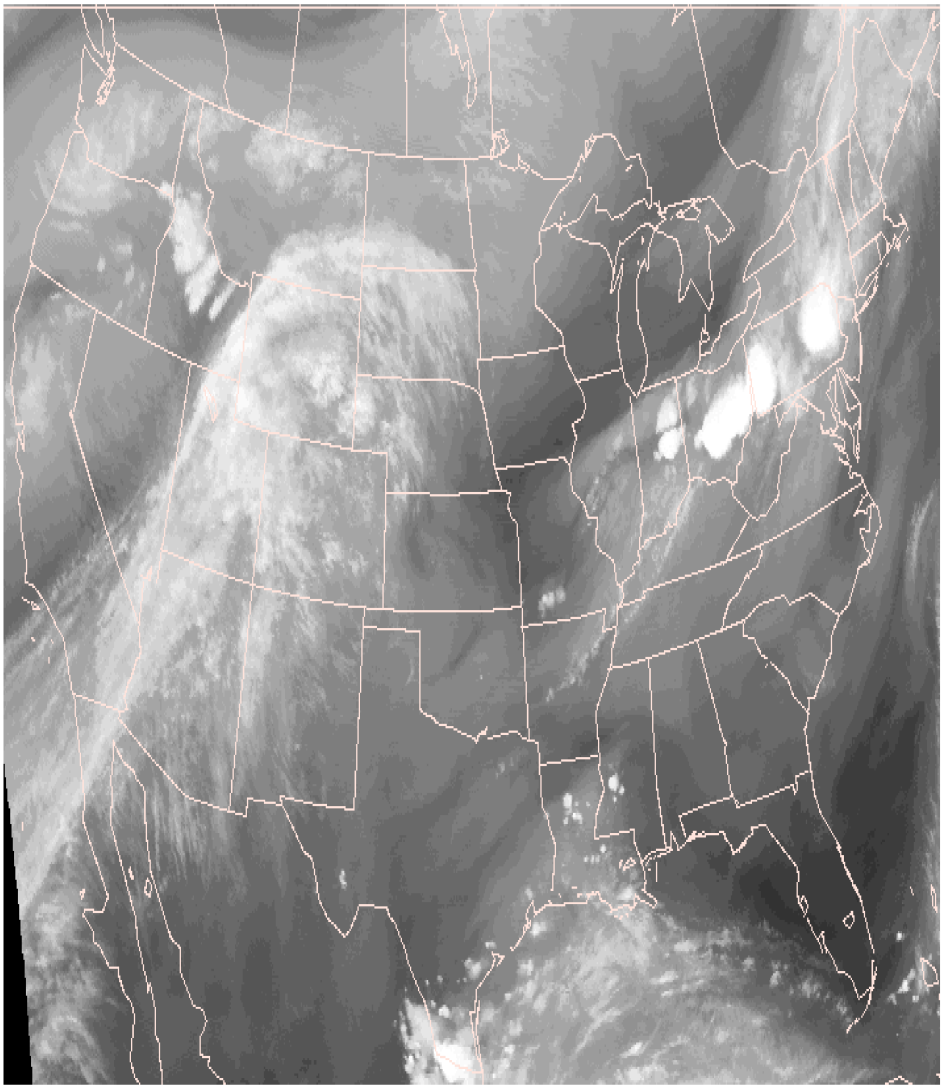
weather technology: infrared imagery

- These images come from satellites which remain above a fixed point on the Earth (i.e. they are "geostationary"). The infrared image shows the invisible infrared radiation emitted directly by cloud tops and land or ocean surfaces. The warmer an object is, the more intensely it emits radiation, thus allowing us to determine its temperature. These intensities can be converted into grayscale tones, with cooler temperatures showing as lighter tones and warmer as darker.
- Lighter areas of cloud show where the cloud tops are cooler and therefore where weather features like fronts and shower clouds are. The advantage of infrared images is that they can be recorded 24 hours a day. However low clouds, having similar temperatures to the underlying surface, are less easily discernable. Coast-lines and lines of latitude and longitude have been added to the images and they have been altered to northern polar stereographic projection.
- The infrared images are updated every hour. It usually takes about 20 minutes for these images to be processed and be updated on the website. The time shown on the image is in UTC.



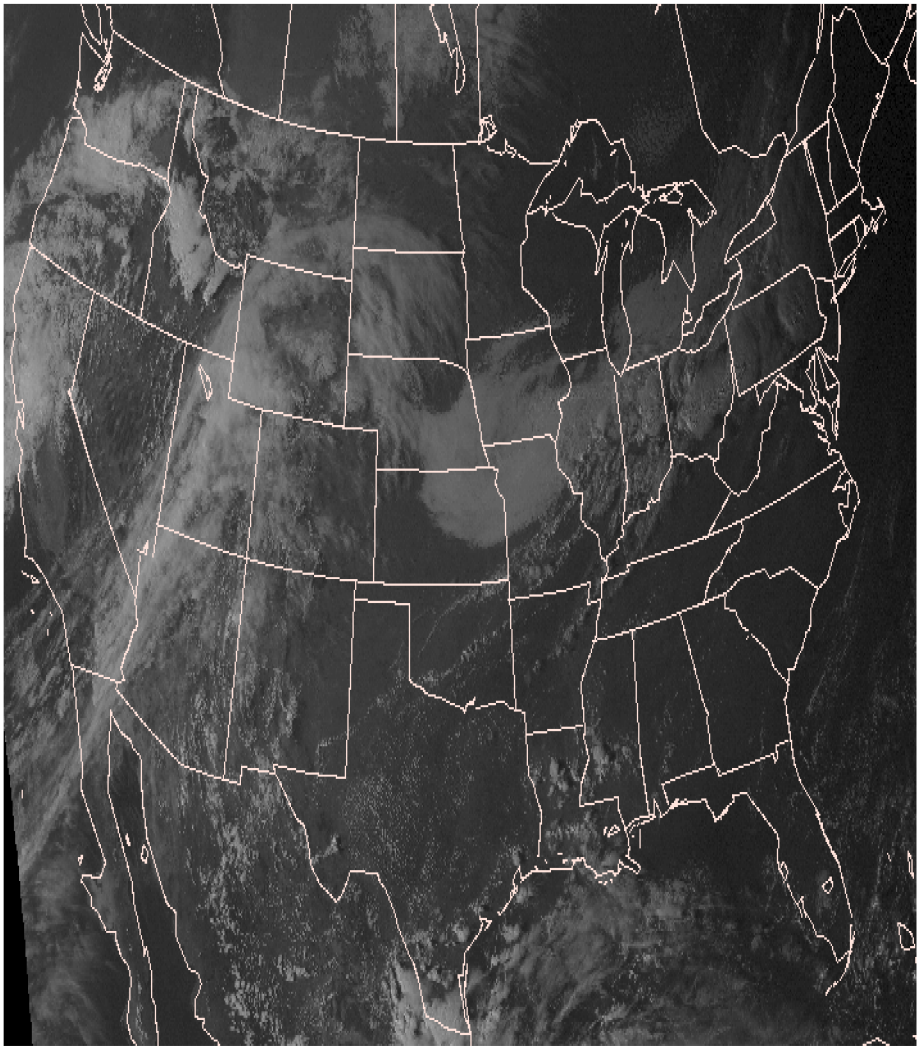
modern weather technology
water vapor imagery

- These images come from satellites which remain above a fixed point on the Earth (geostationary). The image shows the water vapor in the atmosphere and is quite different from the visible or the infrared image.
- The are updated every hour.

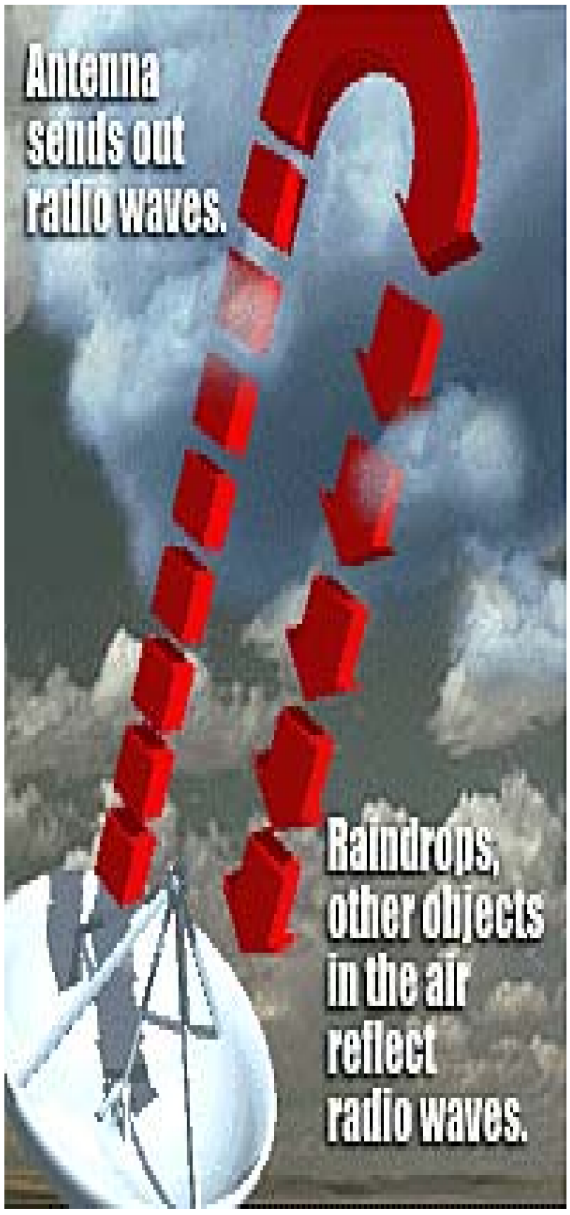


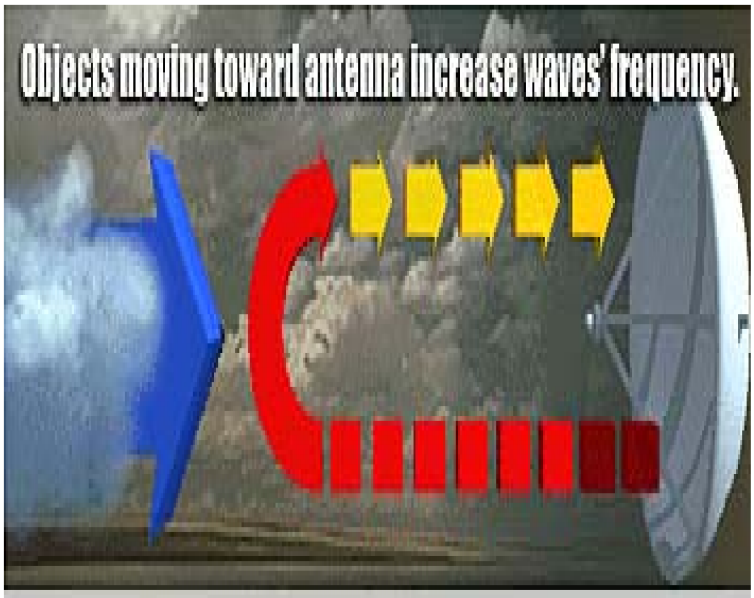
modern weather technology
visible light imagery

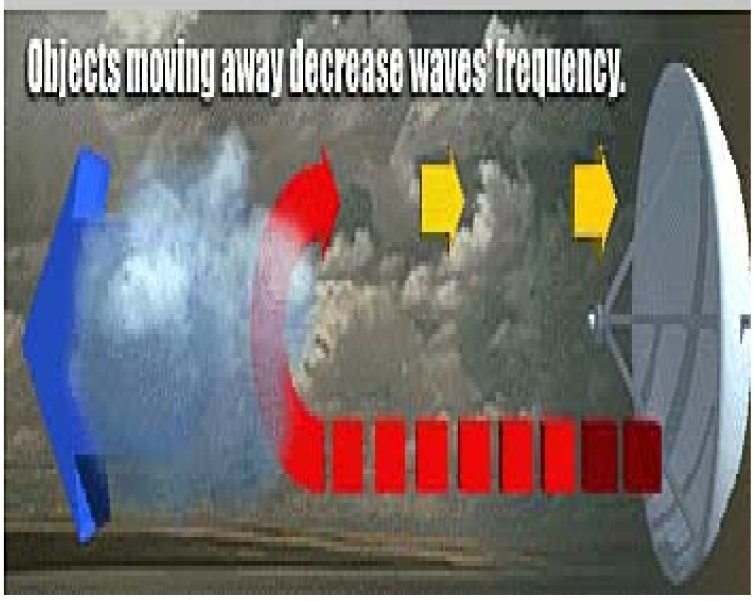
- These images come from satellites which remain above a fixed point on the Earth (geostationary). The visible image record visible light from the sun reflected back to the satellite by cloud tops and land and sea surfaces. They are equivalent to a black and white photograph from space. They are better able to show low cloud than infrared images. However, visible pictures can only be made during daylight hours. The visible images are updated hourly and the time shown on the image is in UTC.



Doppler weather radar – how it works

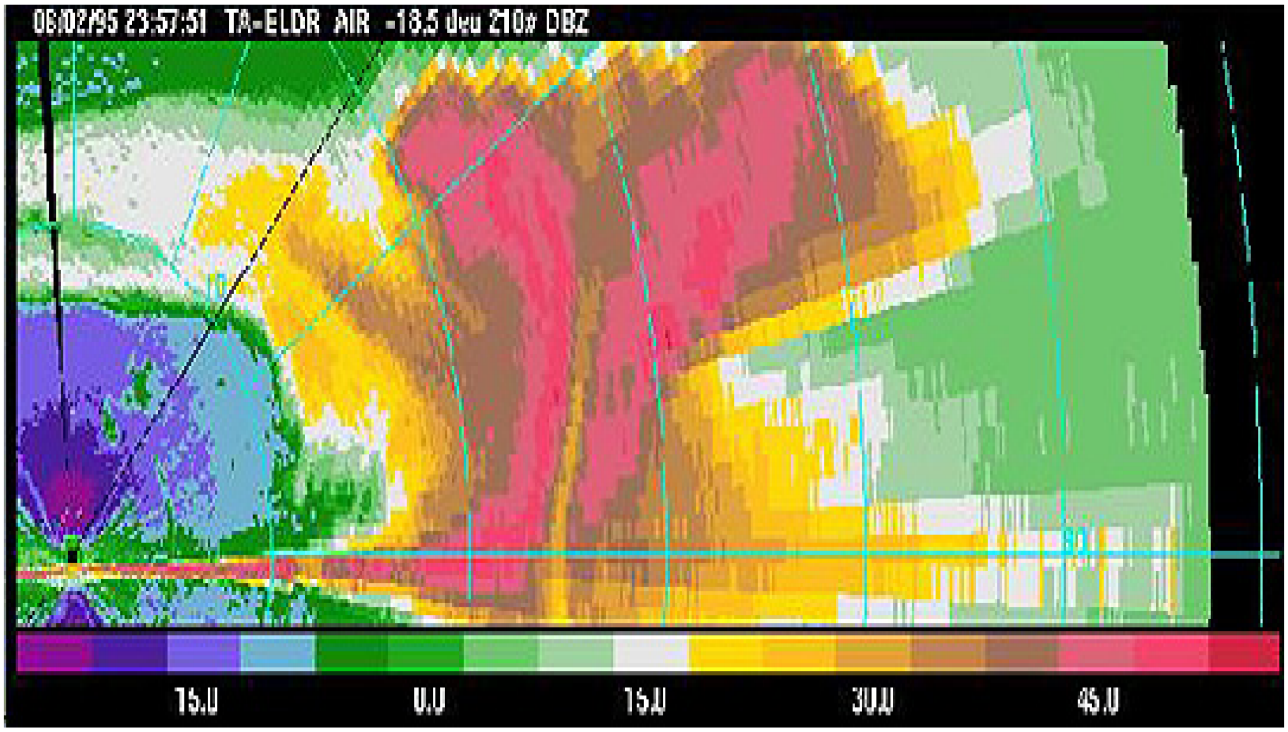






Doppler weather radar – what it shows

- All weather radars send out radio waves from an antenna. Objects in the air, such as raindrops, snow crystals, hailstones or even insects and dust, scatter or reflect some of the radio waves back to the antenna. All weather radars, including Doppler, electronically convert the reflected radio waves into pictures showing the location and intensity of precipitation.
- Doppler radars also measure the frequency change in returning radio waves.
- Waves reflected by something moving away from the antenna change to a lower frequency, while waves from an object moving toward the antenna change to a higher frequency.
- The computer that's a part of a Doppler radar uses the frequency changes to show directions and speeds of the winds blowing around the raindrops, insects and other objects that reflected the radio waves.
- Scientists and forecasters have learned how to use these pictures of wind motions in storms, or even in clear air, to more clearly understand what's happening now and what's likely to happen in the next hour or two.



Doppler weather radar – what it shows

- Precipitation Intensity levels

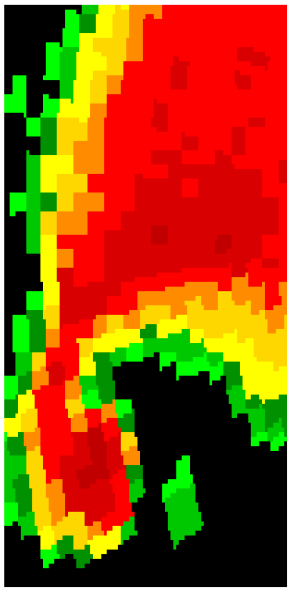
- Radar images are color-coded to indicate precipitation intensity. The scale below is used on radar mages. The light blue color is the lightest precipitation and the purple and white are the heaviest. Sometimes radar images indicate virga, or precipitation that isn't reaching the ground.

- Precipitation type

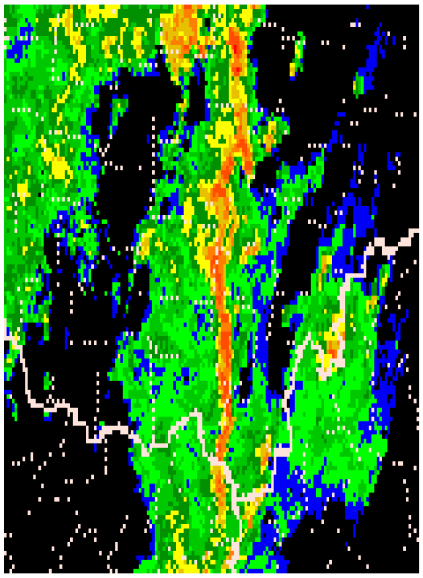
- Reflectivity not only depends on precipitation intensity, but also the type of precipitation. Hail and sleet are made of ice and their surfaces easily reflect radio energy. This can cause light sleet to appear heavy. Snow, on the other hand, can scatter the beam, causing moderate to heavy snow to appear light.

Doppler weather radar – what it shows

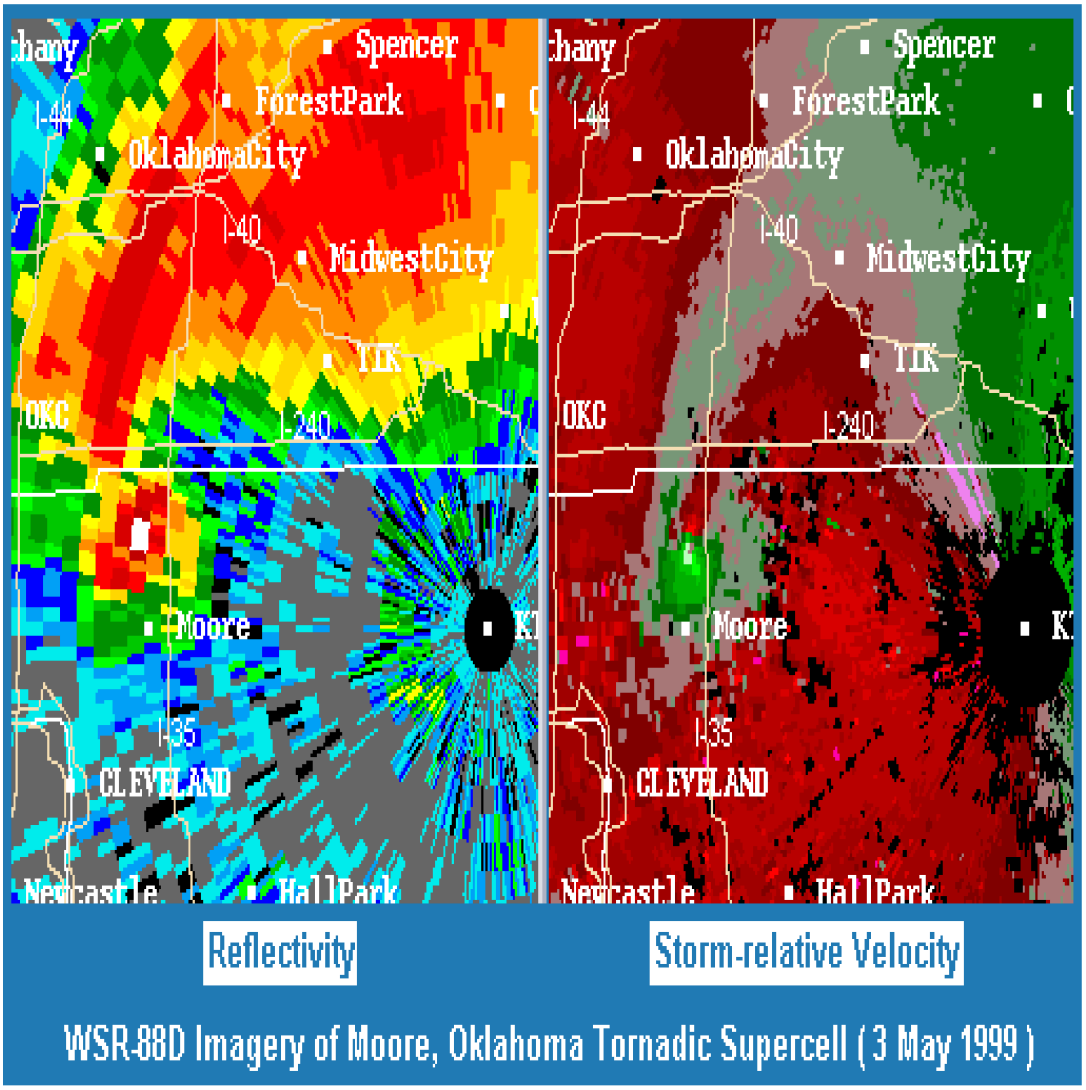
- Hook echo
- These are commonly found in a single thunderstorm, in which the reflectivity image resembles a hook. When this occurs, the thunderstorm is producing a circulation and possibly a tornado. The rain gets wrapped around this circulation in the shape of a hook. In this image, a thunderstorm with a hook echo moves across central Oklahoma May 3, 1999.



- Squall line thunderstorms
- An organized line of thunderstorms is known as squall line. These are common during the spring and are usually triggered along cold fronts. In this picture, a squall line slices across southern Ohio ahead of a cold front.



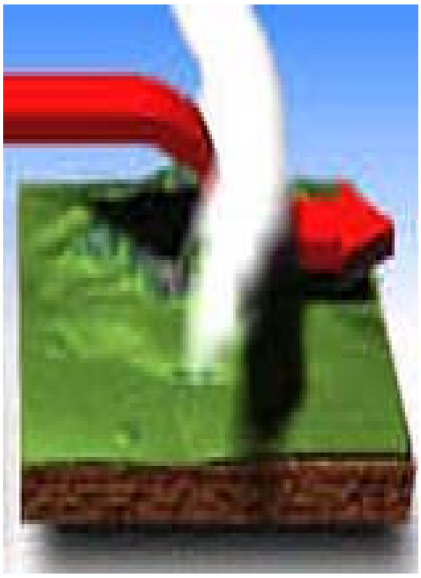
Doppler weather radar – what it shows



- Tornado vortex signature
- Doppler radar can tell when a thunderstorm has Tornado Vortex Signature (TVS). This indicates where wind directions are changing — known as shear —- within a small area and there is rotation. There is also a strong possibility that a tornado will form in that area. A National Weather Service forecaster could issue a tornado warning based on this radar signature.

Doppler weather radar – what it shows

- **Bow echoes**
- **Bow echoes are clusters of thunderstorms that resemble a bow, where the center of the line extends past the two ends of the line. This bow shape is a result of strong winds in the upper levels of the atmosphere that often mix down to the surface.**



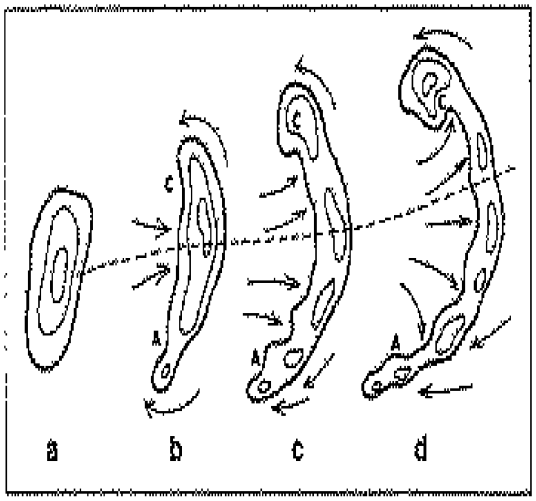
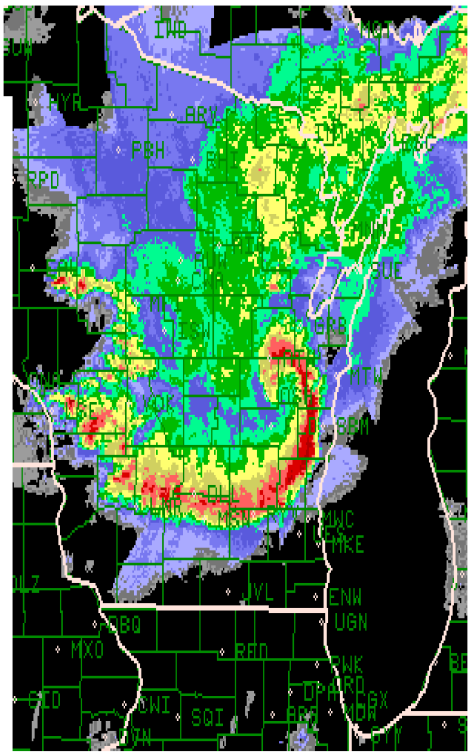


Fig. 1. Bow echo. Typical evolution of a thunderstorm radar echo (a) into a bow echo (b, c) and into a comma echo (d). Dashed line indicates axis of greatest potential for downbursts. Arrows indicate wind flow relative to the storm. Note regions of cyclonic rotation (C) and anticyclonic rotation (A); both regions, especially C, are capable of supporting tornado development in some cases.

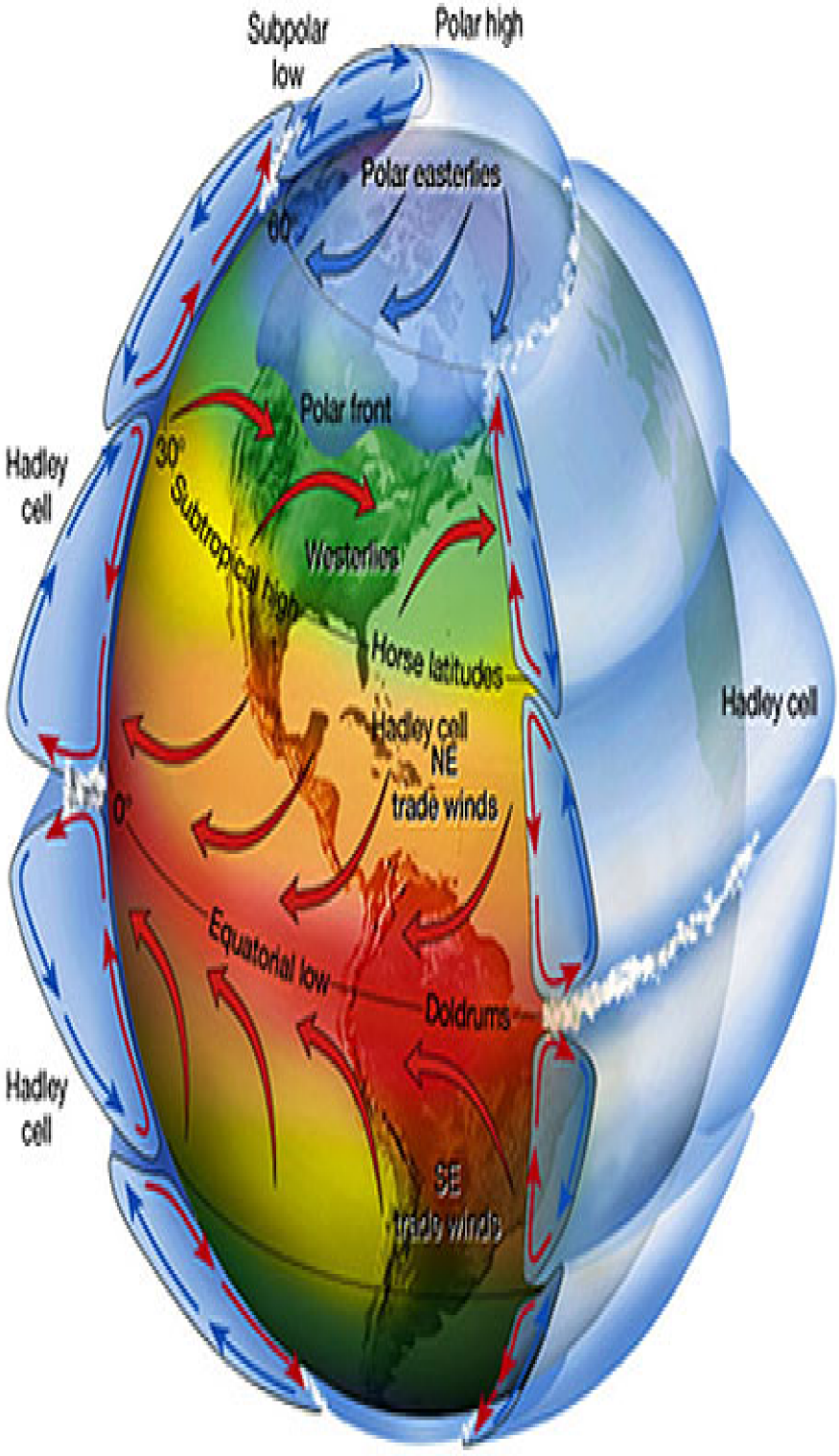


GLOBAL ATMOSPHERIC CIRCULATION: PLANETARY WINDS AND CORIOLIS

- In the three cell model, the equator is the warmest location on the Earth and acts as a zone of thermal lows known as the intertropical convergence zone (**ITCZ**).

- The ITCZ draws in surface air from the subtropics and as it reaches the equator, it rises into the upper atmosphere by convergence and convection. It attains a maximum vertical altitude of about 14 kilometers (top of the troposphere), then begins flowing horizontally to the North and South Poles.

- Coriolis force causes the deflection of this moving air, and by about 30° of latitude the air begins to flow zonally from west to east.



GLOBAL ATMOSPHERIC CIRCULATION: PLANETARY WINDS AND CORIOLIS

- This zonal flow is known as the subtropical. The zonal flow also causes the accumulation of air in the upper atmosphere as it is no longer flowing meridionally.

- To compensate for this accumulation, some of the air in the upper atmosphere sinks back to the surface creating the subtropical high pressure zone.

- From this zone, the surface air travels in two directions. A portion of the air moves back toward the equator completing the circulation system known as the Hadley cell. This moving air is also deflected by the Coriolis effect to create the Northeast Trades (right deflection) and Southeast Trades (left deflection).